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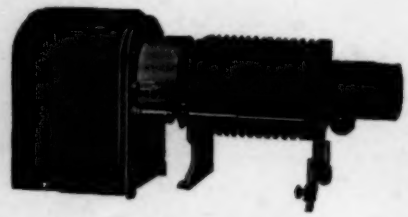

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SCHOOL SCIENCE AND MATHEMATICS

VOL. XXI, NO. 6 JUNE, 1921 WHOLE NO. 179

RESEARCH IN PHYSICS.

Conducted by Homer L. Dodge.

University of Oklahoma, Representing the American Physical Society.

It is the object of this department to present to teachers of physics the results of recent research. In so far as is possible, the articles and items will be non-technical, and it is hoped that they will furnish material which will be of value in the classroom. Suggestions and contributions should be sent to Homer L. Dodge, Department of Physics, University of Oklahoma, Norman, Oklahoma.

THE SIZE OF A MOLECULE.

BY DR. W. W. SLEATOR,

University of Michigan.

Our everyday experience with matter does not suggest to us that it is composed of separate particles. A bit of mercury, for example, may be divided and redivided until the little drops escape our sight, but each one seems to retain the character of mercury so long as we can observe it at all. However, if we reflect upon this process of division, and imagine it carried still further, we see that there are only two possible opinions about it. Perhaps there is no limit to the divisibility. If so, matter is continuous. Or perhaps there is a definite bit of mercury so small that it cannot be divided, and still retain its identity as mercury. If so, then these bits are the units of which a whole mass of the substance is composed. It does not require scientific experience to raise this question. We are not surprised that the Greeks argued about the divisibility of matter, and that interested people took sides upon it. Those who would set a limit to the division were the atomists. The Latin poet Lucretius called the limiting particles "primordia," and he likened their

behavior to the dancing of sheep on a distant mountain-side, whose individual motions leave the flock at rest.

To trace the idea of atoms from the time of the Greeks to the present is not our intention here. The atomic theory, however, seems to have led men into real and dependable knowledge. For now we are clear about the distinction between atoms and molecules, and we know the number of these particles in a gram of any substance, or in a cubic centimeter of a gas, and how much one weighs. We are just getting over the idea that all the atoms of one substance are alike, and we are beginning to understand why their weights come out as they do. We are learning the relation of one kind of atom to another, and to that newer ultimate particle, the electron.

The molecules of a gas move in a perfect vacuum. Between impacts there is nothing to retard their motion. We do not know what a hot molecule would be like, but in a hot body the average velocity of the particles is greater than in a cold one. In the impact of ordinary bodies with imperfect elasticity part of the kinetic energy is converted into heat. Since we cannot conceive of a hot molecule we think that the impacts of molecules result in no loss of velocity. Now although ordinary experience does not show a gas to be relatively viscous, it appears that the viscosity of gases is measurable, and it has been measured. This property depends upon the size of the particles, and measurements of viscosity offer a means of determining the size of the molecules of a gas. There are other ways of making this determination, of which one depends upon finding the limiting volume of a gas under very great pressures, and another upon the value of the thermal conductivity. The results come out about two hundred-millionths of a centimeter. The values given by these different operations are remarkably concordant, and we have every confidence that their order of magnitude, at least, is correct.

These determinations are not completely satisfying now. They tell us the diameter of the molecule, considering it to be a sphere, and we are becoming more and more sure that spheres, especially smooth, equal spheres, do not adequately represent atoms or molecules. Though a single dimension accurately describes a sphere, it does not tell very much about the arrangement of the several positive nuclei and many negative electrons which constitute a molecule. A single number would not inform us completely of the configuration of the solar system,

especially if we did not know how that number was to apply. If we ask now for the size of a diatomic molecule we wish to know the distance between the two positive charges which form the centers of the two systems of discrete and separate electrons. The size of a molecule in this sense has a specific meaning. It is the object of this paper to tell how the lengths of some of these diatomic molecules have been measured.

At the present time a great deal of thought and attention is being given to the investigation of spectra. It is true that in an exhausted tube, and subject to the compulsion of a high electric potential, the molecules of a gas are under somewhat unnatural conditions. What may be inferred about electronic arrangement from such observations does not necessarily hold true for the particle in its normal state. Absorption spectra, however, are not subject to this disability, for a gas may absorb radiant energy when in its natural state, and subject to no special or unusual excitation. It is from the study of the absorption of radiation by hydrofluoric, hydrochloric and hydrobromic acids in gaseous form that our precise knowledge of the lengths of these molecules has been obtained.

Everyone has seen a spectrum, and will remember the band of bright colors with red and violet at the ends. To the physicist, however, the importance of the spectrum does not lie in its color. To him a spectrum expresses the relation between energy and wave length in that pervasive kind of radiation which traverses a vacuum, brings heat and light from the sun, and helps to destroy temperature differences upon the earth. The eye has a range of about an octave in this long continuous scale, where the energy produces our sense of light and color. But it is possible to make a thermometer delicate enough to detect and compare the heating effects in the radiation spectrum through a range of many octaves, particularly through those in which the wave-lengths are too great, or the frequencies too small, to affect the eye. For, though the sun sends us its maximum energy in just the spectral region where the human eye is most sensitive, hot bodies upon the earth, even the hottest ones, being much cooler than the sun, send out most of their energy in the long wave part of the spectrum which is called the infra-red. To the physicist the term spectrum suggests an energy distribution. The curve in Fig. 1 presents in graphic form what such a distribution might be; in particular, it fairly represents the spectrum of the incandescent filament of an electric lamp.

The figure may be so drawn that the area below the curve equals the energy per second sent out by the source. The shaded part shows the range which affects the eye, and even in this limited region not every wave length is equally effective in producing sight. The whole figure explains why an electric lamp must be supplied with more energy than its light represents, and why the efficiency of a lamp increases with the temperature of the filament.

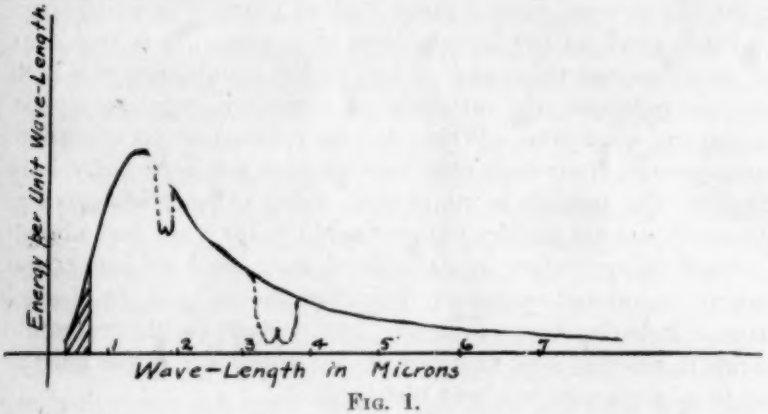


FIG. 1.

Actually to make the measurements from which such a curve as this is plotted requires an outfit of three essential parts. For the source of radiation we must have an incandescent body. The Nernst filament, a little rod of white infusible earths, is perhaps the best, and, because it is heated by an electric current, it is convenient to use. There must then be the dispersing agent, by which the spectrum is produced. This will separate the radiation of the glower according to wave-lengths, and will associate particular colors (except that in the infra-red we should not call them colors) with particular directions or particular positions. Finally, there must be the detecting device, which is to receive at the will of the operator the light (except that we might not recognize it as light) of different wave-lengths or frequencies. This detector must not only indicate the presence of radiant heat, but it must also compare the intensities at different parts of the spectrum. We know that if two wires of different metals are joined together to make a continuous circuit, and one of the two junctions is heated, an electric current will flow through the wires. A row of thermal junctions, a thermopile, so-called, may be placed immediately back of a narrow opening in an opaque surface (the thermopile slit) and joined to a sensitive galvanometer. When so placed that the slit will

receive a small range of wave-lengths in the spectrum it constitutes perhaps the simplest quantitative detector of radiation. In the spectrometer itself no glass may be used, for glass is opaque to infra-red radiation. A clear piece of rock salt may be used to make the prism, in which the actual separation of wave-lengths take place, and instead of lenses, as in a spectrometer for visual work, there will be silver mirrors. These mirrors may indeed consist of silver films on properly shaped glass plates, but the silver must be in front of the glass, not back of it.

In order now to map out the absorption spectrum of any gas, and it is such a process which supplies information about molecular structure, we should have to interpose some of that gas in the beam of light from the glower. This would require a tank with transparent ends, which may be made of mica, or of rock salt, but not of glass. This tank will be swung into and out of the beam, and the corresponding deflections of the galvanometer will show whether or not, and in what degree, the gas absorbs radiant energy. It is the peculiarity of many gases that they do not absorb generally, over the whole spectrum, or any extensive part of it. They seem to pick out one or more particular wave-lengths, or rather certain very small ranges of wave-lengths, the energy of which they noticeably absorb. There are bodies which exhibit this peculiarity in the visible spectrum, and are on this account colored, though transparent, like red glass. Red or blue glass, however, absorbs a wide range of wave-lengths while the absorption bands of a gas may be so narrow as to escape observation in the closest and most refined analysis. If we should plot the spectrum curve, but should use the deflections obtained when a tank of hydrochloric acid, with transparent ends, is interposed in the beam, the result might be represented by the dotted lines in Fig. 1. The curve would show two depressions, each double, at wave-lengths of about 1.7, and 3½ microns, or thousandths of a millimeter. This absorption may be represented in another way. If instead of plotting the spectral energy as a function of the wave-length we should represent the per cent of energy absorbed, the graph would appear as in Fig. 2. The actual fraction absorbed depends of course on the length of the tank, but it is the precise wave-length, or better the frequency, of the radiation lost, rather than the percentage, which gives information about the length of the molecule.

Such a curve as is shown in Fig. 2 presents the results of the earlier work on absorption by hydrochloric acid. There are two doublet bands, each more marked on the side of smaller wave-length. An approximate determination of the length of the molecule may be made from the data presented in such a curve, but the most accurate values depend upon observations made in a somewhat different manner.

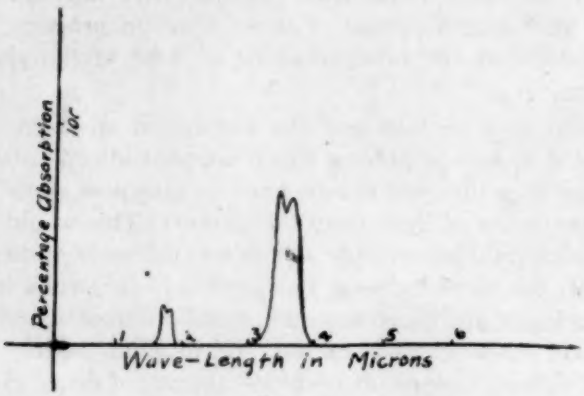


FIG. 2.

Work with such a spectrometer as has been described, when carried to the limit of refinement, requires very narrow slits and a prism of large angle. These are necessary in order to examine the spectrum by small steps. With the best outfits of this kind it appears that the absorption band of hydrochloric acid at 3½ microns is not the simple doublet shown in Fig. 2. Each side, particularly the long wave side, is shown as a series of individual absorption bands. The first public appearance of this fine structure is shown in Fig. 3, which is taken from the work of Eva von Bahr, work done in Berlin, but published in English in the Philosophical Magazine, as well as in the German periodicals. The analysis represented in this figure was somewhat refined by work done with the same kind of apparatus at Harvard, but it appears that the prism spectrometer is incapable of much greater separation of the spectrum. To increase the dispersion further one turns to a diffraction grating.

It is impossible and unnecessary here to go into an explanation of the grating. But its nature and purpose may be described as follows: If parallel and equidistant lines be ruled or cut on the plane surface of a metallic mirror, and a beam of light fall on that surface, part of the light will ordinarily be reflected as from a mirror, but part will be separated into "colors." The

different wave-lengths will be sent away in different directiosn, or at different angles. Moreover, the angle between any two rays of particular wave-length, for example of 1 and 1.1 microns, depends upon the closeness of the rulings of the grating. It has been found possible to obtain rulings so close and regular that the dispersion of the grating exceeds that of any possible prism.

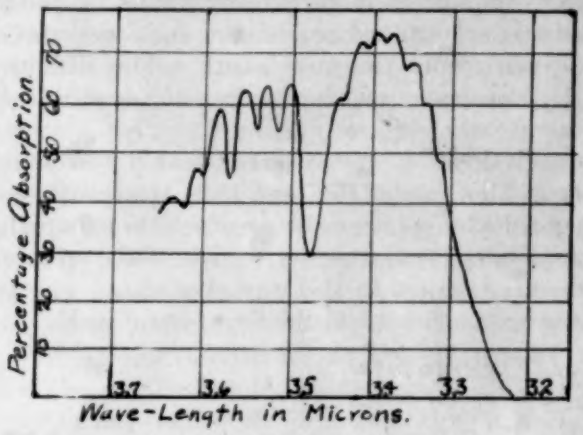


FIG. 3.

The advantage of this device is obvious. It permits a much closer analysis of the spectrum—an examination at smaller intervals, for a smaller wave-length range will affect the thermopile at each particular setting of the grating. Another favorable difference is that the determination of any actual wave-length involved does not depend on knowledge of the optical properties of a natural substance. It depends upon the number of lines per cm. on the grating and an angle to be determined from the apparatus. The grating spectrometer has indeed the defect necessarily incident to its advantage. For when the spectrum is so far extended, the energy is, so to speak, spread thinly over the surface in which the thermopile slit forms a narrow hole. Not so much heat is available at any one setting of the circle, and the detecting system must be more sensitive than is required with a prism. This is the more true because, while the prism employs the whole transmitted radiation to produce a single relatively short spectrum, the grating regularly reflects some of the radiation without separation, and of the rest it makes several, perhaps two, or four, or six, distinct and independent spectra, each one relatively long. It is a farther inconvenience that two or even three of these spectra will overlap. If this is

the case, and a certain per cent absorption is found at a certain setting of the grating, the operator will be in doubt whether the radiation absorbed is of one wave-length or another. For in the first spectrum a wave-length of two microns, for example, is superimposed upon a wave-length of 1 micron of the second spectrum. This ambiguity of determinations by the grating spectrometer is serious, and necessitates such measures of prevention as will render the wave-length values definitive and certain. It is necessary to have to deal, so to speak, with one layer of energy only.

In the work described in this paper, which was done at the University of Michigan in 1917 and 1918, the actual apparatus consisted of a double spectrometer, in which the light first passed through a prism. Then a narrow section of the spectrum was sent to the grating, and in this way overlapping was avoided. The grating spectrometer had the form shown in Fig. 4, where

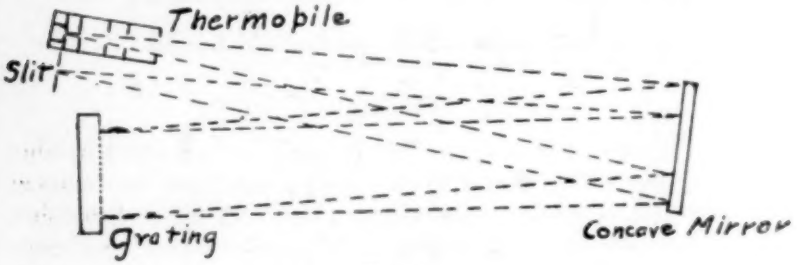


FIG. 4.

the dotted lines show the path of the light. A study of the absorption of light in hydrochloric acid vapor with this apparatus gave the results appearing graphically in Fig. 5. Observations on hydrobromic, hydrochloric, and hydrofluoric acids were made by Dr. Imes, and were embodied in the thesis which he submitted in partial fulfillment of the requirements for the Doctor's Degree. The data had to be secured at night, when the galvano-

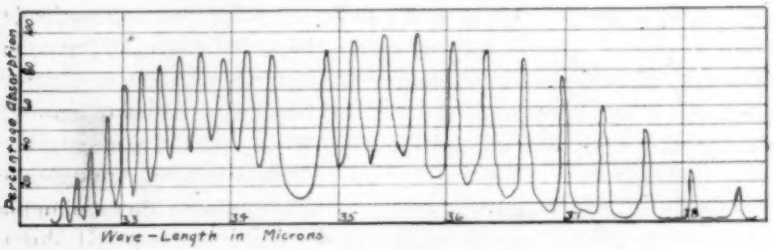


FIG. 5.

meter was steadiest, and every point plotted on the curves, of which Fig. 5 shows but one, depends upon twelve or more independent deflections. This work has been published in the Astrophysical Journal.

It is our problem now to interpret the curve of Fig. 5 in terms of the actual behavior of the molecule, and to deduce from it the molecular length. After a description of apparatus so long and technical, this may be disappointing. Perhaps the reader has expected a picture of the molecule, complete with specifications giving dimensions, velocities, and relative weights. This, unfortunately, the spectrometer does not draw for us. Indeed, as to pictures, even a microphotograph will not come within many diameters of a molecule—will not even indicate the presence of a single molecule, to say nothing of forming an image of one. It is plain then that with all the data before us we have absolutely no value for the quantity we wish to determine, and the most intricate though certainly the most interesting part of our work remains to be done. At the beginning of this interpretation the reader should be warned against an absolute confidence in its result. For it is necessary to have, to start with, an idea of the kind of thing we are to measure. We must apply the knowledge of the spectrum to supply dimensions for a molecule already qualitatively known. Therefore, if we are wrong in our general picture we shall be quite wild in our definite dimension. A man blindfolded and given a little one-inch rule might measure the length of Harper's Magazine and give us his result as the length of the Literary Digest. Being wrong in his idea of the object measured his value would fail to apply. In dealing with the molecule we have no sense of sight, nor even of touch, and a molecule is quiet, and odorless, and tasteless.

However, our idea of the configuration of the little system called the molecule is by no means unfounded. As numerical values for its weight and its dimensions and the relative motions of its parts are found to be consistent, they support each other and the structural hypothesis upon which they are computed. It is by the gradual accumulation of evidence, drawn from different fields of physics, but particularly from investigations with X-rays, that we have come to believe in the nucleus atom. Its center is positively charged, and very small in volume compared to the distances out to the electrons, which are negative charges serving to make the whole atom electrically neutral. We believe

the mass of the atom to lie almost entirely in the nucleus. It is necessary to go even further. The connection between the two atoms which makes of them a stable diatomic molecule is by no means rigid, but has the property of a coiled wire spring. A motion of alternate approach and recession is possible to the two centers—a vibration, in short, of each atom, like the up and down motion of a weight on a spring balance. On the line between the two centers, and nearer the heavier one, is the center of mass of the system. The whole molecule may rotate end over end about this point, so that the two centers (if not in vibration) will describe coplanar circles. Now, on account of these two motions the particle may absorb radiant energy. If it had the vibration alone it could absorb the radiation whose frequency equaled that of the vibration itself (a relation not so obvious as it may seem) and this vibration might therefore result in an absorption band at the corresponding wave-length. It appears, however, that few, if any, molecules have this single motion. Indeed, they all have as well the end over end rotation mentioned above, and the actual motion is a combination of the two. Until very recently we should have gone on to say that all the particles must have the same vibration frequency. That must be qualified now, in the case of hydrochloric acid at least, for not all the chlorine atoms have the same mass. There appear, however, to be only two or perhaps three different masses among the many atoms—three isotopes of chlorine, as the different chlorine particles are called—and accordingly, since the mass may very well affect the vibration rate, there may be two or three different frequencies among the several atoms. Even this is not quite rigorous, for the frequency of vibration will depend in some measure upon the amplitude. But to a degree of approximation adequate to our explanation, we may consider only a single vibration frequency.

This common vibration frequency is combined, in different individual particles, with different rotation frequencies. For it is plain that as the vibratory motion becomes more energetic its amplitude may change with little effect on the vibration rate. But as a particle stores more and more energy by its rotation, that rotation gets faster and faster. This is true unless the dimensions change decidedly, as in this case we do not think they do. Having now these two motions at once, what will be the frequency of the radiation which the particle will absorb?

If we return to consider the curve of Fig. 5, the most strik-

ing characteristic of the spectrum appears to be this, that certain wave-lengths within the whole region are distinguished for marked absorption. The particles pick out, even within this limited spectral region, radiation of certain particular frequencies from which to subtract energy. To explain this selecitve absorption, and relate the frequencies involved to molecular dimensions, it is necessary to consider that new development of physics, which still seems wonderful to us, the quantum theory.

Suppose a rigid body is free to rotate about an axis. Then there are certain speeds only with which it may rotate uniformly. If by some means we accelerate the body its angular velocity changes continuously and perhaps slowly, through all intermediate values, but when left to itself it settles into one or another of its "steady states." For an ordinary body, big enough to be handled, these steady states are very close together so that the difference in speed between two consecutive states is entirely imperceptible. But the spacing in the series of possible velocities depends upon the size of the body, and for a single molecule the changes are relatively great. If the rotating system is composed of several discrete masses m_1, m_2, etc., which are distant r_1, r_2, etc., from the rotation axis, the moment of inertia of the body with respect to this axis, usually written I, is defined as the sum of the products $m_1r_1^2$, $m_2r_2^2$, etc., or $I = \sum (mr^2)$. If ω is the angular velocity of the body $I\omega$ is its angular momentum. Planck's "Wirkungs quantum," the fundamental number h, has the dimensions of angular momentum and in any steady state of the body $I\omega = nh/2\pi$ where n is an integer. This equation specifies the velocity possessed by a particular body in a certain steady state given by the value of n. The value of h is $6.55 \cdot 10^{-27}$ erg seconds, which according to our ordinary experience with bodies is a small number. Evidently for a body as big as a common spool the change in ω corresponding to unit increase in n is very small.

We may now express in letters the kinetic energy of rotation corresponding to any steady state.

For since $I\omega = nh/2\pi$

$$\omega = nh/2\pi I, \qquad \omega^2 = n^2h^2/4\pi^2I^2 \text{ and}$$

$$\text{K. E.} = \tfrac{1}{2}I\omega^2 = n^2h^2/8\pi^2I.$$

The various values of this expression corresponding to n = 1, 2, 3, etc., are the energies of any body whose moment of inertia is I in its several "steady states." In a precisely similar way the theory assigns a series of possible steady states to the vibratory

motion of the molecule. Here the several states have the same frequency but different amplitudes. To these states there correspond energies E_1, E_2, E_3, respectively, which could be more explicitly worked out if it were necessary to do so. It follows that in one of its states of combined vibration and rotation the particle has the energy

$E_1 + n^2h^2/8\pi^2I$ and in the next combination state

$E_2+[(n\pm 1)^2h^2]/8\pi^2I$.

This is on the assumption that I does not change from one state to the next, which is at least an approximation to the truth. The change in rotation state which accompanies an increase in vibration energy may represent an increase or a decrease in the rotation energy, as is indicated by the $\pm$ sign in the second expression.

While a particle remains in a steady state it does not absorb or emit radiation. But in order to change from one such state to another it may do one or the other. What is the frequency of the radiation which supplies the energy necessary for a forward step? We should be inclined to say that the radiation frequency might change with that of the motion, so that the two would be in step throughout the period of the absorption. This would result in the selection from the radiation spectrum not of certain frequencies only, but of all frequencies, a conclusion entirely unsupported by the actual serrated appearance of the absorption spectrum. However, in addition to the fundamental equation defining the steady states, the quantum theory proposes another, which gives the frequency of the radiation absorbed or emitted in changing from one state to another. It is $E - E^1 = h\nu$, where E and E^1 are the energies before and after the change (or vice versa) and ν is the frequency of the radiation emitted or absorbed during the change. h is Planck's constant as before. It appears from this, for example, that the radiation absorbed when a body changes from one steady rotation state to the next higher has a frequency which is the average of the two frequencies of the body itself in the two steady states involved.

$I\omega = nh/_2\pi$ is not in the form ordinarily given for the fundamental equation of the quantum theory, but is deduced for the special case of rotation from a more general statement. In any form which has so far appeared the equation is arbitrary. It is justified rather by the wonderful accuracy of its predictions than by the cogency of its development. The second relation

$E - E^1 = h\nu$ is empirical as the first is, and it is not yet plain that one of these equations may be derived from the other. They are, in short, the fundamental assumptions of the quantum theory. They appear to be so intimately connected either with the nature of the physical world or with the nature of our mental processes that so far they have received no a priori justification. It may some time be possible to express these propositions in a more obvious form, and their justification, whenever it appears, will be a most important scientific advance.

We suppose, in order to explain the absorption spectrum of Fig. 5, that many, though by no means all, of the particles of the gas are changing from the first to the second steady vibration state. In any one particle this change may be accompanied by a change in rotation state which is in some particles a step upward requiring absorption, and in others a step downward, allowing emission. It is not necessary that in every particle the two changes occur simultaneously, but in some at least they will. It is not unreasonable that the stimulus which excites the particle to one shift should also provoke the other. For a molecule which permits atomic vibration is not rigid, and an increase in its rotation speed might somewhat unsettle its vibration. At any rate we have set down the energies before and after a double shift as follows:

Before, total energy $= E_1 + n^2h^2/8\pi^2I$

After, total energy $= E_2 + [(n \pm 1)^2h^2]/8\pi^2I$. The difference in total energy is $(E_1 - E_2) - (\pm 2n + 1)h^2/8\pi^2I = h\nu$.

Therefore the frequency of the radiation absorbed is $\nu = [(E_1 - E_2)/h - h/8\pi^2I] \mp n(h/4\pi^2I)$. In the absorption appearing in this particular region, a vibration change accompanies any rotation change upward or downward between any consecutive rotation states of the whole series. Then we will

let $[(E_1 - E_2)/h - h/8\pi^2I] = \nu_0$ and we have

$\nu = \nu_0 \mp nh/4\pi^2I$. This equation explains the individual bands in the absorption spectrum. From the center or empty space the two bands next on either side correspond to $n = 1$, the two second bands correspond to $n = 2$, and so on. Since one band of a pair has the frequency $\nu_a = \nu_0 + nh/4\pi^2I$, and for the corresponding one $\nu_b = \nu_0 - nh/4\pi^2I$,

it is obvious at once that $(\nu_a - \nu_b/2) = nh/4\pi^2I$, or, in words, one-half the difference between the frequencies of corresponding bands gives us the quantity $nh/4\pi^2I$. This is indeed the rotation frequency of the particle in the particular steady state given by

the value of n. n is the number or order of the pair, and π and h have numerical values, as we know. This equation gives us the value of I, the moment of inertia of the molecule. In the case of hydrochloric acid, for example, we may let m_c and m_h represent the masses of the chlorine and hydrogen atoms, which are known, and r_c and r_h their distances from the axis of rotation. Then $I = m_c r_c^2 + m_h r^2_h$. Since the rotation axis passes through the center of mass $r_c/r_h = m_h/m_c$. We have here simultaneous equations which may be solved at once for r_c and r_h, the two unknowns. Then

$r_c + r_h = L$, the length of the molecule.

This is the definite dimension we started out to find. From Dr. Imes' data the values for the lengths of the molecules, for $n = 1$ in each case, are as follows:

Molecule	Length
HF	$0.94 \cdot 10^{-8}$ cms.
HC1	$1.28 \cdot 10^{-8}$ cms.
HBr	$1.42 \cdot 10^{-8}$ cms.

It is possible that these values may be changed a little by new data, if Dr. Imes' measurements should be improved upon. It may happen indeed that a complete change in our idea of the molecule will upset the calculations entirely, but they appear now to be well founded. It remains to recognize and explain an important element in the appearance of the absorption spectrum of Fig. 5. In this figure the bands are not equally spaced. This is because changing from one rotation state to another affects the energy of vibration, so that the term

$(E_1 - E_2)/h - h/8\pi^2 I$, which we called ν_o,

is different for each particular rotation state. Each pair of bands has then a different center, and these centers shift toward greater wave-lengths as n increases, so that at one end of the absorption region the bands are crowded together, and at the other relatively spread apart. It may be noted also that if the particle should absorb radiation, due to a change in vibration state only, we should have

$\nu = (E_1 - E_2)/h$, and this differs from ν_o

by $h/8\pi^2 I$. Evidently then the mid-point between the two bands of any pair does not correspond to the vibration frequency. That frequency is in fact one-fourth the way from one band to the corresponding one, since $h/8\pi^2 I$ is $\frac{1}{2}$ of $h/4\pi^2 I$.

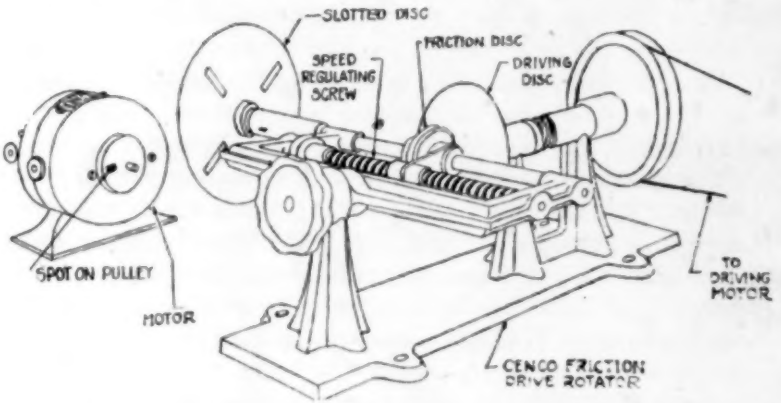
This manner of explaining these absorption spectra is due to Sommerfeld.

A STROBOSCOPIC METHOD OF MEASURING HIGH MOTOR SPEEDS.

By W. H. Farr,

Central Scientific Co., Chicago, Ill.

A problem which often confronts the electrical engineer is that of measuring the speed of very small motors running at a high speed. Tachometers are available reading as high as 10,000 R. P. M., but even the best of tachometers consume sufficient power to slow down a small motor considerably. Sometimes the motor may be so mounted that it is not convenient to attach a tachometer. The ideal method for rating such motors would be one which does not require any mechanism to be attached to the motor itself and therefore does not affect its speed. Also it should be sufficiently flexible to cover a wide range of speed.



The writer has been using for some time a stroboscopic method for rating small motors which satisfies the above requirements. This method employs a second spindle, capable of being rotated at a variable speed. This is adjusted to rotate synchronously with the motor under test only at e. g. 1/2, 1/3, or 1/4 of the motor speed. The speed of the spindle is then found with a tachometer or speed counter and multiplied by the proper ratio. The apparatus employed and the method of synchronizing used in making this test are as follows.

A small spot, such as chalk mark or a small paper sticker is placed on the armature or pulley of the motor. A disk having two or more radial slots, symmetrically disposed, is mounted on the spindle of a Cenco Friction Drive Rotator. As the number of slots in the disk determines the ratio between the speed

of the disk and that of the motor, the number of slots used depends on the speed of the motor under test. The rotator is driven by a constant speed motor, and is so arranged that the spot described above can be observed through the slots in the disk.

The motor under test is allowed to come up to constant speed. The rotator is then started, and gradually speeded up by means of the friction drive mechanism, meanwhile the spot on the small motor is observed through the slots in the rotating disk. A convenient arrangement of motor and rotator is shown in the accompanying drawing.

When a synchronous speed has been reached, only one spot is seen and it is apparently standing still. This means that one slot passes the eye of the observer for each revolution made by the motor. The speed of the spindle of the rotator (i. e. the speed of the disk) is then measured with a speed counter or tachometer.

This speed multiplied by the number of slots in the disk, gives the speed of the motor under test. For example, if the rotator when synchronized is found to have a speed of 1,500 R. P. M. and the disk used has four slots, the speed of the motor is 6,000 R. P. M. Even if the speed of the motor is fluctuating, this method can still be used, provided a direct reading type of tachometer is employed. In such a case the speed of the rotator is adjusted from time to time to correspond with the speed of the motor, and the corresponding readings of the tachometer noted.

The following are some of the outstanding features of this method of speed measurement.

1. It can be used for very high speeds, the only change necessary to adapt it to higher speeds being to substitute a disk having more slots.

2. On account of the fact that there is a fairly high ratio between the speed of the motor and that of the rotator, the rotator need not run at a high speed, e. g. not over 1,800 or 2,000.

3. A high degree of accuracy is possible. In fact, the accuracy is practically limited only by that of the tachometer, as it is possible to get almost perfect synchronism between the motor and the rotator.

4. No matter what type of tachometer is used, the motor

which drives the rotator has sufficient power to drive it without slowing down appreciably.

5. Unless a high degree of accuracy is desired, almost any type of tachometer or speed counter may be used to determine the speed of the rotator. The speed of the motor driving the rotator remains sufficiently constant to permit of measuring this speed with an ordinary revolution counter and a watch.

SOME NEW EXPERIMENTS WITH TUNING FORKS.

By W. H. Farr,

Central Scientific Co., Chicago.

A short time ago the writer was rating some special tuning forks of a rather low pitch (117 and 127) which were provided with "shutters" on the ends of the prongs. In tuning the above forks the original plan was to tune a "standard" fork to the desired frequency and then tune the others to this standard, using the usual method of filing the second fork until the "beats" were eliminated, so far as the ear could detect. However, during the course of this work it was observed that if two of the forks with shutters were struck and one fork observed through the slit in the shutters of the other, an interesting stroboscopic effect resulted. The slit in the shutter of the second fork appears to open and close, each cycle (opening and closing) corresponding to an audible beat. This suggested the idea of using optical interference in comparing an unknown fork with a standard.

This method was employed in rating the above forks and proved to be very rapid, and more accurate than tuning by ear. The readings are almost instantaneous, and very small differences in pitch may be detected, a difference of one-tenth vibration per second, or one beat in ten seconds being easily observed.

It is not the writer's intention to present the above phenomenon as a new discovery, as this phenomenon has doubtless been observed before, but rather to call attention to some new experiments which it suggests for the physics teacher in the line of visual demonstration of interference. With two forks of the type described, one of them being provided with a sliding weight on each prong, the experiments described below may be performed. By adjusting these weights the pitch of one fork may be lowered, and any desired degree of detuning may be obtained; in other words, the rapidity of the beats may be regulated at will.

1. Hold one fork close to the eye and the other almost at arm's length, and observe the slits in the second fork through the slits in the first. When both forks are vibrating the slits of the second fork will appear to alternately open and close.

2. Observe the prongs of one fork through the slits of the other when both are vibrating. The two prongs of the second fork appear to alternately diverge and approach, each cycle corresponding to one beat.

3. Project a beam of light through the slits of both forks, the slits being parallel to each other. The light streak will be seen to appear and disappear, if the forks are out of tune. In this way the phenomenon may be demonstrated to a large class.

4. Test the sensitiveness of ear for detecting small differences in pitch. Adjust the sliding weights on one fork until the ear can just detect a difference in pitch of the two forks. Then measure this difference by counting the number of beats per second.

5. Tune a string of a violin or sonometer to about the same pitch as the fork (or an octave higher). Set the string in vibration and observe through the slit in the fork. The string will be seen to sway back and forth, the effect being similar to a slow moving picture of the vibration of the string.

6. Mount a siren disc on a rotator, preferably the Cenco friction drive type which is driven by a constant speed motor, and adjust the speed until the tone emitted by one of the rows of holes is in tune with the fork. Now observe the disc through the slits of the fork. If the tuning is perfect the holes will appear to be standing still. If the disc is out of tune the holes will appear to be moving slowly either forward or backward, the speed of travel being proportional to the difference in pitch.

7. When the disc has been tuned to the fork, measure the speed of the disc with a speed counter or tachometer. Using this figure and the number of holes in the disc, calculate the rate of the tuning fork. This experiment illustrates the principle used in rating tuning forks by the stroboscopic method.[1]

8. Knowing the rate of the fork and the number of holes in the disc, it is a simple matter to calculate the speed of rotation of the disc. This experiment illustrates the principle used in synchronizing a motor by means of a tuning fork.

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[1](See S. S. & M. Vol. XX No. 2 Feb., 1920, p. 144-6).

A NEW MEANS OF ATTACKING NONPARALLEL FORCE PROBLEMS.

By H. E. Brown,

W. M. Welch Scientific Company, 1516 Orleans St., Chicago, Ill.

It is the belief of the writer that the subject matter and material presented in the High School Curriculum *is being*, and *will be still more* linked with our industrial achievements. Two general and immediate causes for this trend may be mentioned in passing: (1) The passage of the Smith-Hughes and other Vocational Educational bills which opens so many possibilities and which has been taken so much in earnest by educators disseminating agricultural knowledge, and (2) The increasing demand by parents and patrons that the young person be able to *do something* giving better earning power after finishing the course in our public schools and which has resulted in the search for the

The Truss Unit.

happy medium in this "teaching a trade" and "making a gentleman."

Passing from causes to results, we witness the establishment of evening classes, continuation schools; and in our high schools the introduction of textile courses, automobile courses, printing shops, sheet metal shops, foundries, etc., all parented by the now almost essential wood working and machine shop. Further evidence is found by examination more particularly of modern physics texts.

Fig. 1.

Let us consider for example some of the problems in a certain text.[1]

Solution of such problems as these will make clear many of our industrial achievements, and show that the success of these problems depends upon carefully thought out dimensions and details of construction.

[1] Black and Davis.

Instructors have so far found practically only one way of demonstrating the more complex of these problems as indicated in Figs. 3 and 4. This is by use of the Crane Boom. It has usually been used only in the construction as shown in Fig. 1.

It may also be used in a more complex problem. One combination which has been suggested and shows the use of pulleys and their multiplying effect is shown in Fig. 2.

It may be noted that neither crane boom is clamped in the opening of the clamp in which it stands. This makes all joints free to turn and results in a balanced polygon of forces.

In order to aid instructors in the solution of such problems as shown in Fig. 4, and to permit of advance in teaching

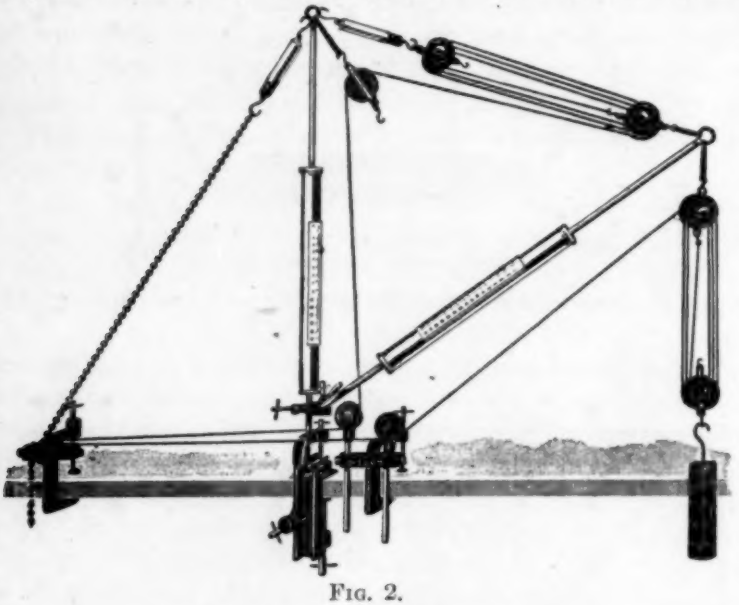


FIG. 2.

along these lines by making possible the solution of further problems it has seemed advisable to present some instrument or apparatus for making possible economically putting such problems in the laboratory for student solution by the experimental method.

Accordingly there has been designed and built such an instrument or apparatus manufactured by W. M. Welch Scientific Company, 1516 Orleans St., Chicago, Ill.

We shall call this instrument or apparatus a TRUSS UNIT,

First considering three nonparallel forces at a point—the most common form of problem which is shown in Fig. 3.

This problem may also be solved without a force board or spring balance or weights by using standard laboratory supports to hold 3 Truss Units as shown. The expense is not increased, a large clumsy piece is omitted, more gradual changes are possible, and with less friction than on a board. By use of these

FIG. 3.

same pieces many more very practical experiments may be performed. This apparatus will fit any laboratory manual which discusses the nonparallel force problem. It is evident that the experiment may be performed from a single illustration or example shown in the lecture room.

Coming to the more industrial problems, such as derricks, an experiment on this important subject can be put in the hands of the student at very low cost by simply using this in connection with ordinary laboratory supports. Two set-ups are shown in Fig. 4.

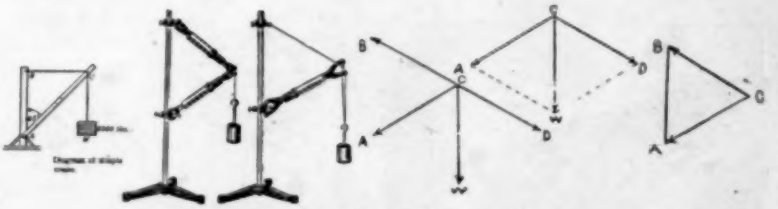


FIG. 4.

METHOD FOR ATTACKING THE PROBLEM.

What is the compression in the crane boom?

Draw diagram as follows (letters refer to parallelogram ACDW Fig. 4).
Make CW proportional to the force.
Make $\angle ACW = 60°$
Complete parallelogram.
By measurement we calculate AC.
Read truss unit before and after adding weight.
We find compression in boom.
Does it prove your calculation?

What is the force in the tie wire?

Set as in Fig. 4, second figure.
In the fourth figure of Fig. 4 CB = CD in direction and size.
Put a weight on hanger.

Read before and after adding weight.
We find stretch in the wire or truss unit.
Does it prove your calculation?

This test also introduces the closed triangle method of solving force problems in which AB is resultant of BC and AC. (See Fig. 4, last figure.)

This instrument can also be applied to the solution of roof truss problems as in Fig. 5.

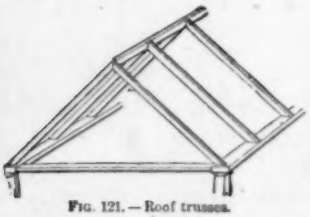


FIG. 121. — Roof trusses.

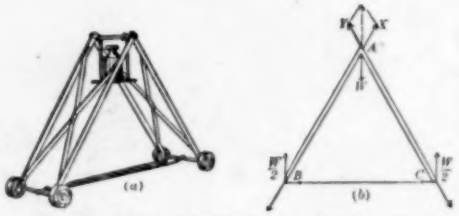


FIG. 122. — Experimental roof truss and force diagram.

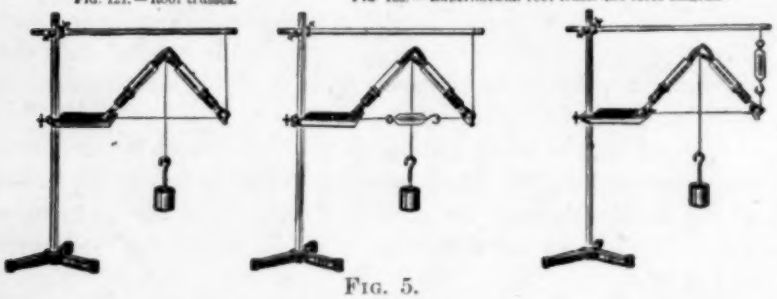


FIG. 5.

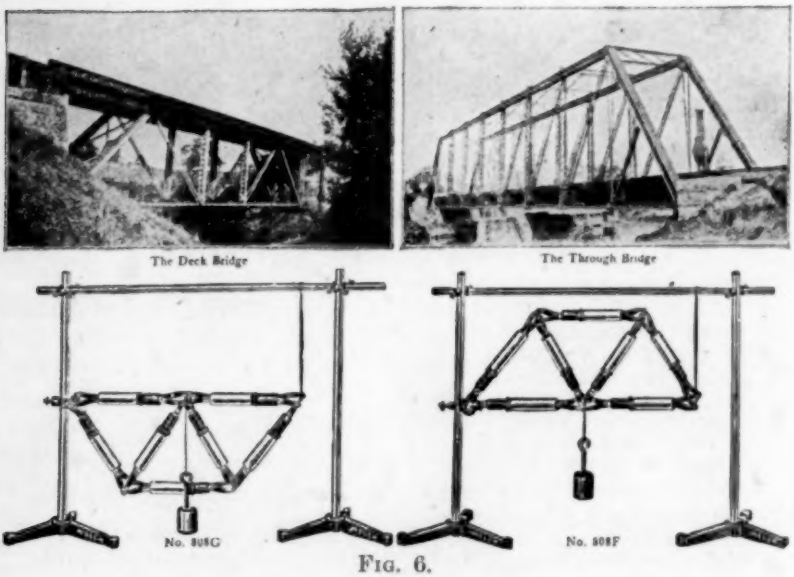


FIG. 6.

This test is set up with the truss units as a third unit at the bottom and fulfills all the requirements. (See Fig. 5.)

Applying it to bridges, it furnishes data as to the nature and amount of stresses in these structures. (See Fig. 6.)

A single qualitative question may be asked by saying: "In which member of the through birdge is there a stretch and in which a compression?" Off hand this is difficult to answer. The diagram in Fig. 7 shows the answer and the set-up of apparatus as in Fig. 6 shows the truth of the answer. This makes it clear as to what members would pull asunder and what members would buckle if too much weight were applied to the bridge. This explains why in the through bridge the outer members are made of compression beams (on the top and ends) and why the diagonal members are relatively small steel rods.

FIG. 7.

This sort of problem goes farther than the high school teacher will find time to take a class, but it is mentioned so as to indicate possible further applications.

FIG. 8.

The development has been followed fairly closely, but these instruments may be used in demonstrating principles of non-parallel forces and methods of their solution with any text.

Besides such problems as have been discussed, there are others which are important and practical that may be chosen. Some of these are quite difficult of solution and others are comparatively simple. Only one will be mentioned here, that has not been taken from any text. Setup as in Fig. 8. Ordinary laboratory supports may be used to support this polygon at the points where the handle bars are supposed to be attached and at the hub of the rear wheel.

Accompanying this problem should be such questions:

(1) Suppose a 165 lb. man sits on the seat, what is the strain in each tube of the frame?
(2) If the man rests half his weight on the handlebars how are the stresses in the tubes affected? (Note that this relieves them of half the weight.)
(3) If the man stands on the pedals and rides how are the stresses in different parts of the frame affected?
(4) What is the effect on each member of the frame when either wheel goes over a bump? How should the rider rest his weight in order to make the strains in the tubes least when going over a bump? Which tube is most likely to give way in such case?

No doubt other forms of industrial applications may occur to the individual teacher, but let those mentioned above be considered as typical uses of this instrument. The most important problems are such as:

(1) The three forces at a point, verifying the principle,
(2) The suspended arc lamp or hammock,
(3) The derrick,
(4) The roof truss,

in their various forms. These make the most valuable as well as the most simple problems and are especially suited for student work. If these questions are covered in the high school course by means of a laboratory experiment, it will indeed be a good foundation in nonparallel forces and will be sufficiently thorough so that the ordinary abstract methods will be more easily handled later. To do any of these experiments requires only three Truss Units.

OLD LENSES AND SPHERICAL ABERRATION.

In these days of high prices we hear of many photographers who are tempted to purchase an old-fashioned long-focus rapid rectilinear lens, using only the center of its field in preference to paying the higher price for a first-class anastigmat. Quite apart from the wisdom or unwisdom of this, says *The British Journal*, there is, however, one caution that should be given to the user of one of the older rapid rectilinear lenses, if he would avoid unsharp negatives, by reason of the lens being uncorrected for spherical aberration; that is to say, the peculiarity of some of these instruments often being of different focus at different stops. The older photographer used to lenses of pre-anastigmat days, will doubtless be fully aware of this, but the warning is necessary to those whose experience has been limited to the more modern, well-corrected instrument. When using an untried rapid rectilinear lens, particularly if of an old pattern, the image upon the groundglass should be carefully examined with the stop that is to be used when making the exposure in position, since the alteration of the stop may have the effect of making a previously sharp image decidedly unsharp. Nor is lack of correction for spherical aberration entirely confined to the older rapid rectilinear instruments, for we have found it present in a lesser degree with some cheap instruments of more recent manufacture. Modern workers are so unused to looking at the effect of stopping down, in affecting the sharpness of the image adversely, that a caution in the matter is not out of place.—[*Photo-Era*.

CLASS-EXERCISE TYPES IN HIGH SCHOOL MATHEMATICS, WITH NORMS FOR JUDGING THEM.

By G. W. Myers,
College of Education, University of Chicago.

I

To the several different types of thinking that are involved in High School mathematical study, specific types of class exercise correspond more or less closely. For example, to the conceptual type of study we have the class exercise of conceptual type, to the associational type of thinking the associational type of class exercise, to the assimilational type of thinking the assimilational type of class-exercise, etc. To profit highly by the study of any given class exercise the student of teaching practice should, first of all, determine the type of class exercise he is concerned with, and then apply appropriate norms in judging it. It is the purpose of this paper briefly to point out the most significant types of class exercise that high school mathematics teaching exemplifies and to indicate norms for judging the several types. It would seem that such a paper ought to be of interest to at least three classes of readers, viz.: (1) visiting mathematical teachers who employ their free visiting days studying observationally the work of neighboring schools; (2) teachers in training in colleges of educational and normal schools, and (3) those in charge of the training of teachers in training.

The following are the most general as well as the most important types of mathematical class exercise met in high schools:

I. The conceptual type
II. The expression type
III. The associational type
IV. The assimilation type
V. The review type
VI. The drill type
VII. The problem type
VIII. The topic type
IX. The application type
X. The test type
XI. The research type
XII. The appreciation type

The point here is that all these types of class exercise need to be recognized as such, and for any really profitable study of one of them the specific norms appropriate to it must be applied. In the sequel, we shall attempt to specify the appropriate norms, or criteria, for judging each of the foregoing exercise types in order.

The Conceptual Type and Critical Norm.

The conceptual type of class exercise is an exercise whose primary and leading intent is to clarify and establish the fundamental notions of the subject, or topic. Among the various types of exercise it is of first, and perhaps of chief importance.

It requires a certain kind of organization, preparation and presentation. The specifications for judging a particular example of this type of class exercise must get at an appraisal of these three things. The leading specifications, which we have called norms, for judging this type of exercise are as follows:

1. What are properly the fundamental concepts, and were they treated?
2. Were they vividly and graphically presented? Illustrate.
3. Were the pupils prepared for them and interested in them? Illustrate.
4. Was the presentation direct or indirect? Graphic or formal? Illustrate.
5. Were the concepts presented through the agency of formal definitions, or through descriptions, explanations, diagrams, etc.? Illustrate.
6. Cite any strong or weak points in the presentation.
7. Was there any recognition of individual differences? Illustrate.
8. Suggest any ways of strengthening the weak places.

The Expression Type and Critical Norms.

In mathematical subjects generally, and particularly in algebra, it is desirable now and then to devote a class exercise mainly to teaching, or to giving facility in, the language and expression modes of the subject. All who know the facts will agree that the mastery of the symbolism of any mathematical branch is a very consequential part of the problem of mastering that branch. One good writer[1] holds that analysis, the direct use of symbolism, the extended use of symbolism, and the manipulation of symbolism are the characterizing activities of the study of algebra. Three of the four characteristics pertain to symbolism. Most of us would perhaps regard a claim that three-fourths of the problem of mastering algebra is a language and expression problem, as putting the case too strong, nor need it be thought that the author just cited makes such a claim. There is no claim by this author that the four characteristics are entire quantitative equivalents. There can, however, be no difference of opinion that the interests of economic progress in any mathematical subject require at times the focussing of teaching effort for one or more class exercises upon the expressional types of the subject. Pertinent questions for a critical appraisal of the expression type of class exercise for mathematics are the following:

1. Did the teaching emphasize most the form, or the content? Illustrate.
2. Was the pupil trying to communicate trivial, or important ideas?
3. Was the content partly from the field of general human experience, or entirely from the narrow field of the science itself? Illustrate.
4. Was the emphasis upon giving command of the expression tools for everyday purposes, or for purely technical purposes? Illustrate.

[1] T. P. NUNN: The Teaching of Algebra.

5. Were the standard language and symbolism of the science taught?
6. Were situations interpreted, or was the expressional work only translating from verbal to symbolic language, and the reverse?
7. To what extent did pupils manifest antecedent practice?
8. Were pupils interested and attentive?
9. Were correctness and good form duly impressed?
10. Did the teacher exemplify his precepts in his practice?

The Association Type and Critical Norms.

Most of the objectives sought formerly through memoriter modes are nowadays being sought by good teachers through the association type of memorizing. Resemblances, differences, relationships in both content and form of mathematical matter, are the modern technics that are largely replacing the still common practice of reliance upon a "dead heave" of formal memory. The association type of thought, of which there is much need in mathematics, is greatly facilitated by a teaching technic that derives the necessary memory factors and products of mathematical thought through association. Many class exercises may well be spent on work that is little more than pure association of the particular with the general, as in substitution work, or of the general with the particular, as in generalizing. Deriving a formula for one of the medians of a triangle, and then writing the formulas for the other two medians *by analogy*, and the like procedure for the altitudes, are examples of associational thinking, and class exercises of which this mode of thought is the outstanding feature are of frequent occurrence. Norms for a critical study of the associational type of class exercise are:

1. Were the associations of ideas actually made by the pupils?
2. Were the generalized types employed properly grasped by the pupils?
3. Were the things associated put together properly?
4. Were symbols connected with meanings, or simply with other symbols?
5. Did the teacher initiate wrong habits by suggesting wrong connections?
6. Were any cross-connections (correlations) established, as arithmetic or geometry with algebra, etc.? Illustrate.
7. Were distinctions of known and unknown, variable and constant, duly familiar to the class?
8. Were any means employed for ascertaining whether pupils were making correct associations? Illustrate.
9. Did the work tend to develop flexible or inflexible study habits in pupils? Illustrate.
10. Suggest any ways of improving the procedure.

The Assimilation Type and Critical Norms.

If, as the writer readily concedes, "only such processes as frequently occur in the lives of all persons should be habituated through drill,"[2] there is very little in either high school algebra

[2] J. H. MINNICK: The Recitation in Mathematics, Math. Teacher, March, 1920, p. 121.

or geometry that needs drill. But for ready mastery of many topics and processes of the later work, both early algebra and geometry contain many things that need to be *well known*. Partial knowledge of fundamentals is elusive, fleeting and disappointing. Beginning pupils are prone to think they comprehend, when in fact they know only very superficially. This is even more true of the brighter than of the slower pupils. All need some repetition of fundamentally important things that they may really apprehend, not that they may be habituated. Repetition, or reteaching, only to the extent called for by increased stability and firmness of grasp of related ideas is assimilation work, and not drill work. Drill seeks to routinize, to automatize, to reduce reflection to reflex; whereas assimilation seeks only stable understandings, and conclusions of belief. Many class exercises of the assimilation type occur and are needed in high school mathematics, and useful norms for the critical study of this type of class exercise are as follows:

1. Did the teacher seem to distinguish between repetition for assimilation and repetition for drill? Illustrate.
2. Was the assimilation given at the right time?
3. Did the class seem to be in need of it? Illustrate.
4. To what extent were individual differences of need for assimilative work evident?
5. Was the class aware of the fundamental character of what they were being required to assimilate?
6. Did the repetition, or reteaching, seem to be achieving its objectives? Illustrate.
7. Were synopses, resumés, or other devices used to show the class the fundamental character of what they were being required to learn well?
8. To what extent, if at all, did the work merely repeat former treatments in the identical ways first given? Illustrate.
9. To what extent, if at all, were new uses and applications employed for assimilation purposes? Illustrate.
10. Suggest any ways in which the class exercise might have been improved.

The Review Type and Critical Norms.

Next to the drill type of class exercise the easy-going teacher and program administrator favor the review type, if frequency of occurrence as a class exercise and as a topical heading in current texts can be construed as a measure of favored exercise types. Review and drill have long been the shibboleths of the mathematical school-master, and their coercing influence on teaching practice until recently, have had much to do in bringing this practice into its present disrepute. A review that is a new view, a higher view, or a more perspicuous view of a study-unit is both highly valuable and essential to good teaching technics. A review that only repeats the old thing in the old way,

which is far too completely the prevalent type even today, needs perhaps to be judged and criticized out of existence. The second sort of review, which is only a means of trying to supply the lacks of inefficient teaching in the first instance, needs extinction by the shortest possible route, though we still frequently meet with the advocacy of this type of review by the violent critics of current teaching of high school mathematics. A visiting teacher is sure to meet the review type of class exercise frequently and criteria, such as the following, for judging its character, will be found useful:

1. Was the review given at the proper place?
2. What was the scope, or ground covered? Determined by a program or by the needs of the class?
3. Was it a recapitulation, a sort of synoptical study, or did it seem only a repetition?
4. Did it so emphasize the major and minor elements of the study-unit in hand as to help to a firmer grasp of the entire unit? Did it prepare well for the next advance?
5. Were the questions and problems well chosen and skillfully used?
6. Were enough new elements introduced to hold attention? Was there any reteaching?
7. Did the class seem alert and attentive, and did all participate? Were both class and teacher prepared? Was there too much or too little of it?
8. Did the teacher seem to achieve a definite, set objective? Illustrate.
9. Specify any weak or strong features of the teacher's work.
10. Indicate ways in which the class exercise might have been improved.

The Drill Type and Critical Norms.

If the principle quoted at the beginning of the foregoing discussion on the assimilation type of class exercise is sound, there is little, if anything, in high school mathematics that a teacher ought even to seek to make speedily automatic. Certainly the admonition, "take your time, but be sure you are correct before you answer," is much more frequently needed than are, "Hurry up," "Be quick," etc., in high school classes in mathematics. Most surely the speediest students are not the best mathematical thinkers. A very few exceptional pupils are highly accurate but inordinately slow in their work. In general a degree of speed is essentially conditioning as to accuracy. That there is a sort of correlation of speed and accuracy is almost certain. Nor is the correlation factor either negative or near $+1$. Some drill for speed is not without warrant, even in the interests of accuracy. Drill for automatism is, however, out of place in algebra and geometry. Granting that the laws of signs, the laws of exponents and a few other elemental matters need drill enough for easy and certain application, we do not concede that the extended drills on factoring and fractions and the

like, that are still too general, are pedagogical, or even justifiable. Such drills as are implied by directions like, "Do as many of the following exercises as you can in fifteen minutes" are to be unqualifiedly recommended. We have, however, granted the claim that drill for facility, for easy mastery, and for economy of time is sound, and very much more drill than is justifiable is met in the observation of current practice. It is, therefore, desirable to be able to apply to drill exercises the appropriate criteria:

1. Was the drill premature, i. e., started before the ideas were well apprehended?
2. Were all pupils engaged all the time?
3. Did pupils go at it with zeal and spirit, and ask for more?
4. Was it concentrated on specific points, or scattering?
5. Were appreciable results gained?
6. Was the device of "working under time-limits" employed?
7. Was it too long continued?
8. Any evidence that it was given to supply the lack of good teaching?
9. Was there any recognition of individual differences and peculiarities?
10. Did it animate or depress the spirit of the class?
11. Were any standard tests employed? If so, what?

We have now discussed six of the standard types of class exercise, and have already, perhaps, transgressed the limit of patience of the editor. There remain, however, the problem, the topic, the application, the test, the research, and the appreciation types of class exercise to be given similar treatment in a later paper. If agreeable to the editors these treatments will be given in a subsequent issue.

Chicago, April, 1921.

SNAP-EXPOSURES ON A TRIPOD.

The rapid aiming of a hand-camera with a fair degree of accuracy is an accomplishment acquired only after some considerable practice, which, doubtless, many otherwise expert photographers know to their cost in the shape of negatives wasted through this cause. In these days of short-focus lenses this is a matter of far greater difficulty than the focusing of the picture. When making photographs of public ceremonies, processions, etc., it is a good plan, if the photographer is not very expert, for him to find some convenient coign of vantage, such as the upper window of some adjacent building. There he can erect the camera upon a tripod, thus making sure of its accurate focus and direction before the time to make the pictures arrives. In this way it is quite easy to make a number of exposures with the advantage that the photographer knows exactly what is included in the picture, leaving him quite free to watch the subject and give it and its most favorable poses his undivided attention. The limitations of the view may be mentally marked by the vertical lines of buildings, etc., though a slight latitude is also allowed by a turn of the instrument upon its tripod-screw to right or left, should the subject move off the predetermined spot. Photographers are so inclined to think of instantaneous photography as inseparable from hand-camera work that they do not realize the value of a tripod.—[*Photo-Era*.

THE FUNCTION CONCEPT IN FIRST YEAR HIGH SCHOOL MATHEMATICS.[1]

By J. M. Kinney,

Hyde Park High School, Chicago.

Fundamental Character of Functionality.

Functionality is a principle of very wide application. It is not at all confined to the field of mathematics. Wherever we find the dependence of one thing upon another there we have the principle of functionality exemplified.

The profits made by a business man depend upon the amount of his sales and his expenses. These in turn depend upon many other factors. The crops depend upon, among other things, the weather, the soil, and the industry of the farmer. The occupation of the people of a community may depend upon the presence of a certain kind of raw material. The time of the vibration of a pendulum depends upon its length. The distance through which a body falls depends upon the time. The side of a triangle, the other two sides being fixed, depends upon the size of the angle opposite. There is practically no limit to the number of instances of functionality that may be cited.

Functionality is one of the most, if not the most, fundamental notions of mathematics. Should we not therefore recognize this fact in the teaching of high school mathematics?

Of course it should not be our aim, especially in the first years, to make a study of functions. During these years the attention of the pupil should be called to numerous examples of relationships which exist between quantities and the nature of these relations. Thus a foundation may be laid for the formal study of functions just as it is laid for the study of demonstrative geometry through work in intuitional geometry.

I do not wish to leave the impression that the organization of a course in elementary mathematics about the notion of relationship is for the sole purpose of preparing the pupil for advanced work in mathematics. On the other hand I feel that elementary mathematics taught from the functional point of view is the most practical sort of mathematics for preparing the pupil for any sort of work, or for giving him an appreciation of mathematics. If he has been trained to think in terms of relationships in his mathematical problems it seems to me that he has been best fitted for thinking in the same terms in connection with the problems of life.

[1]Read before The Chicago Mathematics Club April 15, 1921.

OUTLINE OF THE PLAN FOR DEVELOPING THE FUNCTION CONCEPT.

The formula. In his grammar school mathematics the pupil has been given various rules for making computations. By way of example he has learned that the number of feet, having given the number of yards, may be obtained by multiplying the number of yards by 3. He will now be delighted to find that this rule may be expressed in a form of shorthand as

$$f=3y.$$

The rule expressed in this form exhibits the close relation existing between f and y. The teacher need not at first stress this relationship. He need merely have the pupil evaluate one of the letters by giving the other various numerical values. After the pupil has learned how to evaluate he should make a table which exhibits corresponding values of the letters and obtained by assigning to one of these letters consecutive numbers which have a common difference. From this table he sees that a uniform change in one of the letters produces equal changes in the other.

The material upon which he should practice for many weeks should belong to the simplest type, viz., $y=ax$. There is an abundance of material which gives rise to formulas and relations of this type. The following topics offer excellent opportunities for pointing out such a relationship between certain magnitudes.

1. Perimeters of regular polygons, rectangles, and circles.
2. Percentage and interest.
3. Similar triangles.
4. Trigonometric ratios.
5. Forces on an inclined plane.
6. Motion on an inclined plane including velocity of falling bodies.
7. Uniform motion.
8. Elongation of elastic cords and spiral springs.
9. Arithmetic progressions whose starting terms are 0.
10. The linear variation $y=kx$.

The relation $y=a+bx$ is a bit more complicated and quite naturally follows a study of $y=ax$. Numerous formulas of this type which are of interest to the pupil and which have intrinsic worth may be found. As in the case of the simpler relation the pupil may be made conscious of the nature of the relationship through drill in the evaluation of one of the letters for a given value of the other. He should be led to see that a uniform change in x is accompanied by a uniform change in y and conversely.

Many of the topics mentioned above as being suitable material for use in the study of $y=ax$ may be used in the study of $y=a+bx$. Thus problems on selling prices and amount involve percentage and interest. Then there are problems on motion of bodies on an inclined plane whose initial velocities are not 0, on lengths

of elastic cords and spiral springs, and arithmetic progressions whose starting terms are not 0.

We come not to the quadratic types. Of these, two are of especial interest to first year pupils. They are simple hyperbolic and parobolic types $z=axy$ and $y=a+bx+cx^2$. Under the former we find such formulas as those of areas of certain plane figures, work, and power. By making z a constant we obtain the inverse variation $xy=k$. The parabolic type is rich in problems from geometry, physics, and mechanics. The majority of them give rise to the pure quadratic relation $y=ax^2$.

Just as in the linear formulas the pupil should get his first notions of relationship represented by these formulas through evaluation.

The graph. Relationships between magnitudes may be vividly exhibited by means of graphs. These should be introduced early. The pupil should associate each relation with its corresponding graph.

SOME SPECIFIC EXAMPLES EMPLOYED IN DEVELOPING THE FUNCTION CONCEPT.

I shall now give some specific situations which illustrate the various types of relationships mentioned above. These examples are selected from a course in first year high school mathematics which I have been developing during the past four years. They are based on simple commercial, geometric, physical, and mechanical material.

(a) The type $y=ax$.

(1) Perimeters. The formula $p=4s$, in which s means the side of a square, is one which is easily understood by the pupil. By computing values of p corresponding to given values of s the pupil is led to see the dependence of p upon s. Conversely, by solving the formula for s for various values of p the pupil gets practice in solving equations of the type $ax=b$, and sees that s depends upon p. In either case he should see that the letters are related in such a way that equal changes in the one is accompanied by equal changes in the other. In an exercise based on this formula and others like it such a question as the following should be asked.

How is the perimeter effected by making the side of the square twice as long; three times; four times; n times?

The perimeters of other regular polygons and the circumference of the circle should be studied in the same way.

The formula for the perimeter of the rectangle is a bit more complicated. Such questions as the following may be asked.

Do you obtain equal changes in the perimeter of the rectangle for equal changes in the length? In the width?

If the length of the rectangle is doubled, is the perimeter doubled? If the width is doubled, is the perimeter doubled? If both the length and width are simultaneously doubled, is the perimeter doubled?

(2) Simple interest. The formula $i=prt$ can be obtained easily by the pupil as the shorthand expression of the rule for computing simple interest. Questions similar to those concerning changes in the letters of the perimeter formulas may be asked. Thus, if p and r are given fixed values how is i affected by equal changes in t? The point that equal changes in t produce equal changes in i should be stressed in order that later this fact may be contrasted with the fact that equal changes in t in the compound interest formula do not produce equal changes in i.

(3) Stretching of elastic cords and spiral springs. It is an easy matter for the teacher to demonstrate to a class that the amount of stretching in a rubber cord varies as the weight, or force applied. That is $s=kf$. This formula can be made the basis for many interesting problems throughout the course.

(4) Forces on an inclined plane. With a spring scale, a small car, and a smooth board borrowed from the physics department the teacher can verify before the pupils the formulas,

$$p=w\sin i \text{ and } p=w\tan i,$$

which give the relation between the weight of the car and the force required to hold it in equilibrium on the inclined plane. Questions similar to those asked in the previous examples may be asked concerning p and w for fixed values of the inclination i. The teacher may also enquire how p and i work together. He should have the results he wishes to obtain forecasted intuitionally by the pupil. The pupil gets a great deal of satisfaction in seeing that the relationship expressed by a formula checks up with his common sense.

(5) Motion on an inclined plane. With the car mentioned above, a smooth board 16 feet long, and a stop watch or seconds pendulum, motion on an inclined plane may be investigated. Let one end of the board be raised one foot higher than the other. Let the car be released at the upper end and the distance it has traveled at the end of each second till it arrives at the lower end be recorded. The pupils find that at the end of one second the car has moved about one foot; at the end of two

seconds about four feet; at the end of three seconds about nine feet; and at the end of four seconds about sixteen feet. Thus during the first second the car has moved one foot; during the second second, three feet; the third, five feet; and the fourth, seven feet. Thus there is an increase of two feet per second in the velocity of the car. Hence we have the relation $v=2t$. By raising one end of the board two feet above the other the velocity of the car at the end of any second is double its velocity for the corresponding second under the previous inclination. It is not difficult to have the pupil see that the velocity is given by the formula

$$v=32t\sin i.$$

This formula may be discussed in the same manner as the formula $p=w\sin i$. By making $i=90°$, that is, by making the board vertical, we get

$$v=32t,$$

which is the formula for the velocity of a freely falling body.

Later these formulas are used to derive the formulas

$$v=v_0+32t\sin i$$

and

$$s=v_0\,t+16t^2\sin i.$$

(6) Constant change in temperature. Let us suppose that at the present time the temperature is 0 and that for some hours there has been a constant change in temperature and that this will continue for some time in the future. Let T mean the temperature at the time t and c mean change in temperature in degrees per hour. Then

$$\mathrm{T}=ct.$$

This formula is an excellent one not only for the study of dependence, but also for developing the law of signs for multiplication. Thus suppose the change is a rise of 2° per hour. Then $\mathrm{T}=+2t$. By following the change in T from some number of hours in the past to some number of hours in the future the pupil learns that the product of a positive number and a negative number is a negative number and that the product of two positive numbers is a positive number. In a similar manner by making the change a fall in temperature, he learns that the product of a negative number and a positive number is a negative number and the product of two negative numbers is a positive number.

(7) Uniform motion. The formula,

$$d=rt,$$

may be discussed in the same manner as the temperature formula. This formula forms the basis for other formulas on uniform motion.

There are many other formulas of the type $y=ax$ which will occur to you but I believe enough has been said to indicate how this simple form may be treated.

(b) Formulas of the type $y=a+bx$.

There are numerous situations which give rise to formulas and relations of the type $y=a+br$. The pupil may be asked to translate such statements as the following:

(1) A certain society charges \$10 for an initiation fee and \$5 per year for dues. Write a formula which expresses the amount paid in after any number of years (a, t).

This gives the formula $a=10+5t$.

(2) A rule for determining the normal weight in pounds of an adult for a given height is sometimes stated as follows: Multiply the number of inches in the height that is over five feet by $5\frac{1}{2}$ and add 110. Write the formula (w, h).

The formula is $w=110+5\frac{1}{2}h$.

(3) The Chicago Telephone Company's charge for a four-party line telephone per month is as follows: A guarantee of 5 cents per day, i. e., \$1.50 per month, plus 4 cents for each outgoing message above 30. Write a formula for finding any number of messages (c, m) (m = number of messages above 30).

The formula is $c=1.50+.01m$.

(4) The formula for determining the postage on a parcel sent into any zone is easily found by the pupil to be

$$p=f+cw,$$

where f is the charge on the first pound, c is the charge on each additional pound, and w is the number of pounds less one.

(5) I bought an encyclopedia for \$100, paying for it at the rate of \$5 per month. Write a formula expressing the amount due at the end of any month (a, m).

The formula is $a=100-5m$.

(6) If pupils are given the proper preliminary work they can derive the formula,

$$F=\frac{9}{5}C+32,$$

which gives the relation between the readings of the Centigrade and Fahrenheit thermometers.

Through the evaluation of the formulas just mentioned for each of the variables the pupil may be led to see how they work together. He should learn that a uniform increase in one vari-

able will produce a uniform increase or decrease in the other.

I shall now add some other formulas with questions I am accustomed to ask my classes.

(7) A dairyman, who retailed his milk, derived a formula by means of which he could compute the approximate annual profit in dollars on a cow if he knew the average number of pounds of milk produced per day by the cow. The formula was

$$p = 15m - 135,$$

where p = the profit in dollars and m = the average number of pounds of milk.

Construct a graph of this formula. Take the horizontal axis as the m-axis.

Can your graph extend to the left of the p-axis?

From your graph find

(a) the profit when the number of pounds is 16; 15; 14; 13; 9; 6;

(b) the number of pounds required to make a profit of \$15; \$30; \$45; \$60; \$50; \$100;

By means of the formula find which is the more profitable, a cow which gives 15 lbs. of milk per day, or three cows which give 10, 11, and 12 lbs. per day respectively.

(8) When weights of 2 oz., 6 oz., and 12 oz. are suspended from a rubber cord its lengths are found to be 7 in., 9 in., 10 in., and 12 in. respectively.

(a) Construct a graph showing the length for other weights.

(b) From your graph find

(1) the length corresponding to 5 oz.;

(2) the number of oz. when the length is 8 in.

(c) (1) What is the amount of stretch for each ounce added?

(2) What is the original length of the cord?

(3) Write a formula giving the length for other weights (l,w).

(4) Plot the formula on the diagram with your graph.

(9) A railway station B, is 190 miles east of a station, A. A train running on a road passing through A and B is leaving B and going east. Distance east of A and velocity east are considered as positive.

(1) If the train runs at an average rate of 40 mi. per hr., what will be the formula giving the distance, d, from A at the time, t, time being counted from the instant that the train leaves B?

The formula is $d = 190 + 40t$.

(2) Find by the formula
  (a) the distance from A after 3 hrs.; 7 hrs.;
  (b) the distance from A 2 hrs. ago;
  (c) the time required for the train to reach a point -50 mi. from A;
  (d) the time for the train to reach a point 40 mi. from A.

(3) A second train is traveling west at the average rate of 25 mi. per hr. It is now 70 mi. from A. Write a formula giving its distance, d, from A at the time, t.

(4) Find by the formula
  (a) the distance from A after 4 hrs.;
  (b) the distance from A 2 hrs. ago;
  (c) the time when it is 90 mi. from A;
  (d) the time when it is at A;
  (e) the time when it is -80 mi. from A.

(10) Another formula which can be used with various problems on uniform motion is

$$d = d_0 + (r_2 - r_1)t,$$

where d is the distance between the two uniformly moving objects at time t, d_0 is the distance between them when $t = 0$, and r_1, r_2 are their rates.

Let the objects be at the points X and Y at the instant we begin counting time. Let us also make the following agreement as to direction.

1. By first object and second object we mean the objects at X and Y respectively at the instant we begin counting time.

2. d and d_0 are positive when measured in the direction from X to Y.

3. r_1 and r_2 are the rates of the first and second objects respectively and are positive in the direction from X to Y.

The following examples illustrate the use of the formula. Example 1. A train which travels at an average rate of 30 mi. per hr. is now at X and moving toward Y. A second train is now at Y and is moving in the same direction as the first train at an average rate of 45 mi. per hr. The distance from X to Y is 60 mi.

(a) Find their distance apart
  (1) 2 hrs. from this instant;
  (2) 5 hrs. ago;

(b) Find the time at which they were, or will be
  (1) 90 mi. apart;
  (2) 30 mi. apart.

(c) Find when the fast train passed, or will pass, the slow train.

Example 2. The conditions are the same as in Example 1 except that the second train is moving toward X.

(a) How far apart will they be in 3 hrs.?

(b) When were they -90 mi. apart?

(c) When did, or will, they meet?

(11) Constant acceleration. A boy rolls a ball up a smooth incline with a velocity of 30 ft. per sec. Its velocity decreases uniformly at the rate of 4 ft. per sec. till it stops. It then rolls back with the same numerical acceleration it had in rolling up.

(a) Write the formula.

(b) In how many seconds will it stop?

(c) What will be its velocity after 92 sec.?

(d) Find the time when its velocity will be (1) 10 ft. per sec; (2) -10 ft. per sec.

(e) Simultaneous linear pairs.

We come now to the problem of determining how a pair of linear relations may work together. Such pairs may be studied from the tabular, graphical, or algebraic standpoint.

(1) As an example let us suppose that two rubber cords hang from a horizontal support. Let us suppose that one is 30 in. long and stretches 2 in. for each additional ounce weight hung at the lower end; the other is 24 in. long and stretches 3 in. for each additional ounce weight. Can we find a weight which will stretch them to the same length and, if so, what will the length be?

The question may be answered by making a table of corresponding values of weights and lengths as exhibited in the following table.

w	0	1	2	3	4	5	6	7	8
l_1	30	32	34	36	38	40	42	44	46
l_2	24	27	30	33	36	39	42	45	48

As the table is being developed the children see that the length of the shorter cord is gaining on that of the longer and hence if neither of the cords break there will be a weight which will stretch them to a common length.

If the two sets of lengths with the weights are plotted and the graphs are constructed the relation between the lengths is vividly portrayed.

The children may now be shown that we can study the way in which the lengths approach equality by means of the formula,

$$l_1 - l_2 = 6 - w$$

which is obtained by subtracting the formula, $l = 24 + 3w$ from the formula, $l_1 = 30 + 2w$.

If we are interested only in the common value of the lengths the formulas may be written without the subscripts. Thus

$$l = 30 + 2w$$
$$l = 24 + 3w.$$

These equations may be solved for l and w in the usual manner.

I shall now add some other problems which may be treated in a similar manner.

(2) A point moves so that its distance from the x-axis is twice its distance from the y-axis. A second point moves so that the sum of its distances from the axes is 9. Find the coordinates of the point of intersection of the paths of the points.

(3) Water is being pumped from a reservoir A into a reservoir B. The depth of A is now 6 feet, while that of B is 2½ feet. If the level of A is being lowered 8 in. per hr., while that of B is being raised 6 in. per hr., when will they have the same depth and what will that depth be?

(4) Two trains, A and B, are moving east from a city, X. A is 25 miles east of X and is running at an average rate of 40 mi. per hr. B is 50 miles east of X and is running at an average rate of 30 mi. per hr. Find the time when A will overtake B and their distance from X.

(d) Quadratic formulas.

I. The relation $z = axy$. There are many problems giving rise to formulas of this type. Let us consider a few of them.

(1) What effect will it have on the area of a triangle whose base is 8 cm. and whose altitude is 5 cm. (a) to double its altitude; (b) to treble it; (c) to quadruple it?

(2) What effect will it have on the area of a triangle whose base is 12 in. and altitude 9 in. (a) to double its dimensions; (b) to treble them; (c) to quadruple them?

(3) A triangle has an area of 48 sq. in. and an altitude of 6 in. If the area is to remain fixed what effect will it have on the triangle to make the altitude (a) 2 times as large; (b) 3 times as large; (c) 4 times as large; (d) n times as large?

(4) How many times will the area of a trapezoid in which the altitude is 7 in. and the bases 9 in. and 11 in. respectively be increased if its dimensions are made (a) 2 times as large;

(b) 3 times as large; (c) 4 times as large; (d) n times as large?

(5) The sides of a parallelogram are 30 in. and 40 in. respectively and the included angle is α.

(a) Find the area of the triangle if $\alpha = 15°, 30°, 45°, 60°, 75°, 90°$.

(b) Does the area of the parallelogram vary as α?

(c) What is the maximum area?

(6) If the outlet of a bicycle pump is closed and the piston pressed down, the volume of the air under the piston will be decreased. It can be shown that the volume varies inversely as the pressure. Write the variation.

When the pressure is 8 lbs., the volume is 60 cu. in. Find the volume when the pressure is 25 lbs.

Make a table of corresponding values of p and v for

$$p = 4 \quad . \quad . \quad . \quad . \quad . \quad 15.$$

Plot the pairs of numbers in your table and construct the graph.

II. The relation $y = ax^2$. This relation is rich in applications.

(1) The area of a square is given by the formula

$$A = s^2.$$

(a) Make a table of corresponding values of A and s.

(b) Do equal changes in s produce equal changes in A?

(c) What is the area of a square whose side is (a) 2 times the side, 3, of a given square; (b) 3 times; (c) 4 times; (d) n times?

(d) What effect does it have on the area of a square to make its side, s (1) 2 times as long; (2) 3 times; (3) 4 times; (4) n times?

(2) The load that may be safely carried by an iron chain is given by the formula

$$l = 7.11d^2,$$

where l is the load in tons and d is the diameter of a link in inches.

(a) Find the safe load which may be lifted by a chain in which the diameter of a link is (1) $\frac{1}{8}$ in.; (2) $\frac{1}{4}$ in.; (3) $\frac{1}{2}$ in.

(b) In doubling the diameter of the link do you double the size of the safe load?

(3) Show that the area of the line $y = \frac{2}{3}x$ from o to x is $A = \frac{1}{3}x^2$.

(a) Find the area for $x = 3, 6, 9, 12$.

(b) What effect does it have on the area to increase x

(1) 2 times; (2) 3 times; 4 times?

(4) The relation between the stretch of a certain spiral spring and the force applied is given by the formula

$$s = \tfrac{1}{3} f,$$

where f is the force in pounds and s is the amount of stretching in feet.

(a) Show that the number of foot pounds of work done in stretching the spring is equal to the area under the line $s = \frac{1}{3} f$ from 0 to f, that is

$$w = \tfrac{1}{6} f^2.$$

(b) Make a table of corresponding values of f and w giving f the values 1, 2, 3, ...

(c) How do the values of w increase with f?

(d) Show that the consecutive increases in the values of w form an arithmetic progression.

(5) The velocity of a falling body is given approximately by the formula

$$v = 32t.$$

Show that the distance passed through by a falling body in t seconds is

$$s = 16t^2.$$

(The pupil should now be asked questions similar to those of No. 4)

(6) Another problem which children like to solve is the projectile problem in which there is a combination of uniform horizontal motion and motion due to the force of gravity. This problem gives rise to the equations

$$d = ht$$
$$s = 16t^2,$$

where h means the horizontal rate per second.

Example. A bombing plane is flying with a velocity of 60 mi. per hr. at a height of 1,600 ft. A bomb is aimed at an ammunition plant. At what horizontal distance from the plant should the airman drop the bomb?

(The resistance of the air is to be neglected.)

The problem should be solved both algebraically and graphically. In constructing the graph take axes through the point at which the bomb was released. Distance downward should be considered positive.

(7) Another interesting problem is that of a body moving with an initial velocity and constant acceleration. It may be stated in the general form as follows:

A body is given an initial velocity v_0 and changes its velocity at the rate a. (a) Show that its velocity at time t is

$$v = v_0 + at.$$

(b) Show that the distance passed over during the time from 0 to t is

$$s = v_0 t + \tfrac{1}{2}at^2.$$

As a particular case consider the following example:

A projectile is fired vertically upward from a gun with an initial velocity of 1,600 ft. per second.

(1) In how many seconds will it reach its maximum height?

(2) What will be its maximum height?

(3) What will its height be after 10 sec.? When will it be again at this height?

(4) What will be its velocity after 80 sec.?

(5) What will be its height after 80 sec.?

(6) When will it strike the ground?

(7) Construct a graph of your equation and answer the questions above by means of your graph.

(8) There are numerous problems on maxima and minima which may be considered from the standpoint of functionality. The following example will illustrate:

A farmer has 120 ft. of wire fencing with which he wishes to make a rectangular lot for some small calves. He wishes the lot to adjoin a fence and have a maximum area. How far out from the fence will the lot extend? What will be its length and area?

If we let w equal the number of feet in the width it is easy to show that

$$A = -2w^2 + 120w.$$

Hence we are to find that value of w that will give a maximum A. This may be done by constructing a table of corresponding values of A and w and noting that value of w which gives a maximum A. The graph should also be constructed.

The National Committee on Mathematical Requirements has stated that there are thousands of instances in which the teacher may point out relationships between quantities.[2] I hope that the few examples which I have mentioned may be suggestive to you and that you may be able to add to the list. I

[2]See the report on The Function Concept in Secondary School Mathematics.

feel that the high school student should be given during his third and fourth years problems to be treated from the standpoint of the calculus. It seems to me that problems involving questions of variation and functionality are just the ones needed to lay the foundation of such work.

A very large amount of mathematical material presented to our high school people at the present time is made up of conundrums and blind-alley problems. It is but a little more valuable for developing mathematical ability and power in our boys and girls than saw-dust as a food for producing strength in horses.

Let us sift out the saw-dust from our mathematical courses and substitute in its stead a nutritious and wholesome food.

HOW TO DRAW A STRAIGHT LINE.

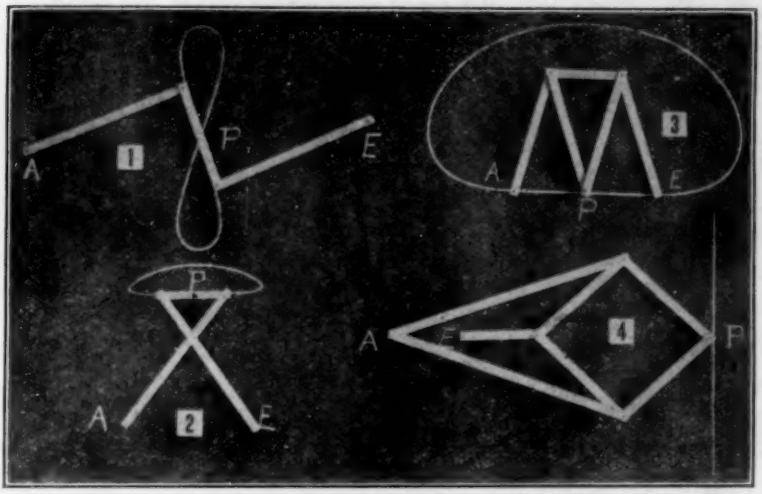
By F. E. Tuck,
Nevada City, California.

To draw a straight line as an original exercise seems, at first thought, to be an exceedingly simple thing for a mechanic or mathematician. The circle, ellipse, and other well known curves which appear much more difficult can be readily described with simple and familiar apparatus. But how would you proceed to originate a straight line? Not by aid of straight-edge or ruler, for this presupposes a solution which you would thus simply copy—a mere begging of the question. To describe a circle with a compass is an original construction but to use a circular cut-out and trace around its circumference would be assuming that which is required.

This article describes several ways by which a straight line may be drawn as an original exercise by means of link motion or linkages. Aided by the models shown in the reproduced photographs the problem becomes a fascinating study of elementary mechanics.

Models large enough for demonstration purposes are very readily constructed from thin strips of wood fastened together with small screws and mounted on a blackboard or other smooth surface. A piece of crayon or lead pencil is used as a tracer and is fastened in the indicated position by fitting it in a small hole bored through the frame to receive it. For individual study smaller models made of strips of stiff cardboard and fastened together with shoemaker's eyelets are very satisfactory. The model should be fastened to a drawing board with thumb tacks over a sheet of paper on which a permanent record may be kept.

In the accompanying drawings, A and E represent pivots or screws with which the model is fastened to the baseboard and about which it rotates. P is the pencil or tracer.



Begin the study of how to draw a straight line with model No. 1. This shows, in its simplest form, a link motion well known to mechanics and engineers, Watt's parallel motion, invented by James Watts in 1784. If the long arms are of equal length and the distance between the pivots A and E is such that when the long arms are parallel the middle link is perpendicular to them, the tracer, which is located at the center of the middle link, will describe an approximate straight line if the apparatus is rotated a small amount. Move the tracer to its extreme positions and a figure eight shaped curve will be the result.

The line described by Watts' apparatus is sufficiently accurate for many purposes—most beam engines employ the device—but it will not solve the problem.

Model No. 2 has two radial bars each 10 in. long and a middle link 8 in. long which carries the tracer at its middle point. The distance between the pivots is 16 in. and between these two points the tracer describes an approximate straight line. If the distance is longer than this a peculiar curved line is traced.

Figure No. 3 gives a closer approximation to a straight line. The four upright links are of equal length and the horizontal link is equal to one half the distance between the fixed points. The path described by the tracer as it moves between A and E is apparently a straight line, but when it passes these limits a peculiar shaped closed curve will result.

But all of these and similar devices fail to describe an accurate straight line. It has been demonstrated that such a line can not be drawn with three links. The solution can be accomplished with five, seven, and other odd numbers of links. An odd number of links must be used to describe definite curves.

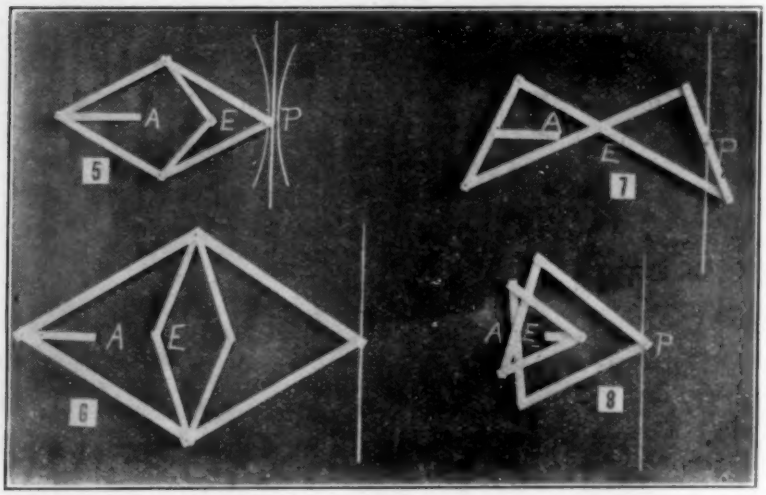
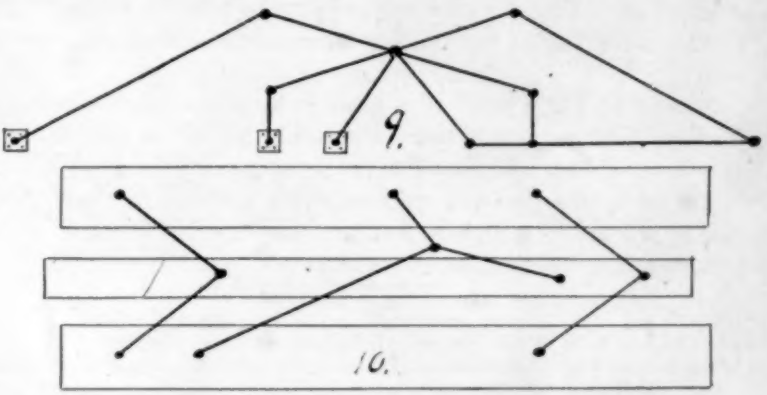


Figure 4 shows a seven-link device of great theoretical and historical interest as well as of considerable practical value. It is the first known apparatus by which an accurate straight line was drawn without the illogical expedient of copying some other, supposedly, straight line. It consists of two long links, equal in length and pivoted together at one end, the other extremities of which are joined to the opposite vertices of a rhombus composed of four equal but shorter links. If an extra link, EF, equal to one half the distance AF be added to this so-called cell, as shown in the drawing, and A and E be fixed points, a pencil fastened at P will trace an exact straight line as the cell is rotated on its axes.

With a working model before you this forms a unique experiment which never fails to attract and interest all who see it. It suggests other possible solutions and modifications and opens a wide field to the ambitious investigator. For example, what will be the effect if the extra link EF should be made a little shorter or longer than half AF? Try it for yourself and you will be surprised to obtain arcs of two extremely large circles, one with the convex, the other with the concave side toward E. This suggests the possibility of constructing a drafting instru-

ment based on this seven-linked device for use wherever arcs of very large circles are required. The free end of the extra link should be mounted on a sliding pivot for quick adjustments.

Figure 7 shows a five-link system which will also describe an accurate straight line. This linkage goes through some remarkable contortions as it rotates about the two pivots but through it all the tracer follows unerringly the straight line path. A remarkable property of this model is that the middle points of the four links always lie in a straight line. Other linkages which can be used in describing a straight line are shown in figures 5, 6, and 8. The first of these may be adjusted in two and the second in four different ways by changing the point of attachment of the extra link and the fixed points.



It is often necessary to have a whole beam, instead of a single point, move so that all points in it move in a straight line as, for example, the slide rest in lathes, traversing tables, punches and drills. This can be accomplished by various combinations of linkages. In figure 9 the horizontal link moves to and fro as if sliding on a rigid horizontal support. Figure 10 represents a double horizontal ruler so constructed that if the lower ruler is held in a horizontal position the top ruler can be moved vertically up and down without any lateral movement whatever.

In addition to the uses already mentioned these models are very suggestive scientific toys for the mechanically minded boy. By changing the position of the tracer and varying the length of the links and the distance between the fixed points a series of strange and interesting results will be developed. Complicated curves can be obtained with the device used to illustrate Watts' parallel motion by moving the position of the tracer from

one end of the middle link to the other, an inch at a time, and tracing one complete, double-looped figure in each position. Sometimes a difference of half an inch in one dimension produces remarkable transformations in the figure obtained. By actual demonstration these models properly explained and presented have proved to be both entertaining and instructive to the casual observer and even to small audiences. They possess the peculiar merit of urging one on to make original research for his own enjoyment and satisfaction.

AN EXPERIMENT IN BIOLOGY BY A HIGH SCHOOL PUPIL OF COLUMBUS, OHIO.

The problem quoted as it stands in Hunter's Laboratory Manual is—"To determine where bacteria may be found." To do this a number of petri dishes were needed, containing sterile agar.

A petri dish is a small, flat glass dish with a cover which fits loosely. Sterile agar is more commonly known as gelatine. A thin layer of this was placed over the bottom of the petri dishes.

To solve this problem we exposed a number of these petri dishes containing nutrient for the same length of time in the following conditions:

(a). To the air of our civic biology class room.
(b). In the halls of the school while pupils were passing.
(c). In the halls of the school while pupils were not passing.
(d). At the level of Pearl and Gay streets, a supposedly dirty corner, for fifteen minutes.
(f). In a downtown theater at the evening performance.
(g). At a lumber company in the north end of Columbus.
(h). To dirt from the hands of a pupil.
(i). To contact with the interior of the mouth of one of the pupils.
(j). To contact with the dust from a dustrag used in the class room.
(k). To contact with a new one-dollar bill.
(l). To contact with three hairs from a pupil's head.

After two days we made a chart and noted the conditions of the various plate cultures on it.

Following is the chart:

		Number of colonies of bacteria			
		Jan. 13.	Jan. 14.	Jan. 18.	Jan. 20.
(a).	To the air of our Civic Biology room	1	5	18	37
(b).	In the hall of the school while pupils were passing	23	75	238	265
(c).	In the hall of the school while pupils are not passing	2	5	20	25
(d).	At the level of Pearl and Gay streets	0	7	12	35
(e).	At the level of Tulane and Indianola	0	5	5	6
(f).	At a theater in the evening	32	59	65	127
(g).	At a lumber company	3	7	24	34
(h).	To dirt from the hands of a pupil	3	7	7	11
(i).	To contact with the interior of a pupil's mouth	0	0	15	16
(j).	To contact with the dust from a dustrag used in the class room	50	238	480	1,023

(k). To contact with a new dollar bill.....	9	22	27	27
(l). To contact with three hairs from a pupil's head.	0	1	1	5

This shows that bacteria are found in the greatest numbers in places where it is dark and dirty and where many people pass by and breathe and exhale the air.

Bacteria do many things which are of economic importance to humanity. Economic importance means the good or bad a thing may do for people.

This experiment made by the pupils of a civic biology class should be a warning to the people of Columbus to look out for such things as promote the growth of bacteria.

Beware of dirty dark corners and not enough ventilation. Open your homes to sunlight and air, and live cleanly, eat good food and watch the results.

Written by Hazel Linn,
3335 N. High St.,
Columbus, Ohio.

Age 14.
9B Civic Biology.
Teacher: Miss Lyndall Diebel,
Crestview Intermediate,
Columbus, Ohio.

SELENIUM A RARE ELEMENT.

Selenium is a rare and little-used element described by the United States Geological Survey, Department of the Interior, as having its greatest use in giving a red color to glass, such as that used on railroads for signal lights, and in coloring enameled ware red. It is also used to overcome the natural green color of ordinary glass. Selenium is peculiar in being a very poor conductor of electricity in the dark and a fairly good conductor in the light and is used in several electrical devices whose utility depends on this peculiarity. It has been used in telephoning along a ray of light and in transmitting sounds and photographs from one place to another over a wire.

FEW PEOPLE HAVE EVER SEEN RADIUM.

Radium is a metal that is described as having a white metallic luster. It has been isolated only once or twice, and few persons have seen it. It is ordinarily obtained from its ores in the form of sulphate, chloride, or bromide, according to the United States Geological Survey, Department of the Interior, and it is in the form of these salts that it is usually sold and used. These are all white or nearly white substances, whose appearance is no more remarkable than that of common salt or baking powder. Tubes containing radium salts glow mostly because they include impurities which the radiations from the radium cause to give light. Radium minerals are very rarely, if ever, luminescent.

IMPORTED PLANTS.[1]

By Henry C. Cowles,

University of Chicago.

When one investigates the geographic origin of our cultivated plants, he is perhaps surprised to discover that hardly any major crop plant of the world originated in the area where it is now most cultivated. In other words, the great agricultural countries of the world depend upon exotics or imported plants, so far as their chief crops are concerned. Not a single crop plant of the first rank has been developed in the United States or Canada. Even in Europe, with its vastly older civilization, the story is much the same. Australia, New Zealand and South Africa, in spite of their great agricultural development, have given nothing of major consequence to the world. Temperate South America has given one important plant to the world, viz., the potato, but this is the only major crop plant that either of the cold temperate zones has ever originated. This is, at first thought, tremendously surprising, in view of the fact that the peak of the world's agriculture today is in these same cold-temperate zones.

Time was when we were in ignorance as to the country of origin of most of our leading crops. The first to dispel a large part of this ignorance was Alphonse DeCandolle, whose "Origin of Cultivated Plants," though written long ago, is still an indispensable book on all scientific shelves. Since DeCandolle's time we have learned a good deal about the origin of certain crop plants, notably wheat and oats. There still are many important crop plants whose ancestral form is unknown, though in most instances we can make an intelligent guess as to the probable wild ancestor and country of origin. In lack of better evidence, we commonly place the original home of a cultivated plant in that country where its closest wild relatives are still to be found. In this way the original home of the coconut, peanut, and sweet potato have been placed in tropical South America, though many have contended for an old-world origin for each of these important plants.

Corn, that most baffling and mysterious of all crop plants, from the point of view of origin, has been thought to have originated in tropical North America, perhaps in Mexico; no crop

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[1]Read before the Biology Section of the C. A. S. & M. T. at the Englewood High School, November 26, 1920.

plant is so alone in the world as corn, but such remote cousins as it still has seem to center mostly in Mexico.

By piecing together our knowledge and our ignorance, we discover that most all of the important crop plants of the world have issued from three centers remote from one another. These centers are Asia Minor, and the surrounding territory, southeastern Asia and the adjoining islands, and tropical America. By plotting centers of origin on a base map of the world, it is strikingly clear that a relatively small part of the land surface of the globe has yielded most of the plants that have been and are cultivated by the human race. Of these three centers, one, Asia Minor, is prevailingly warm-temperate and dry; the other two centers are mostly tropical and humid.

In a plant world made up of thousands of species, the doctrine of chance would lead one to expect that original crop plant centers should be numerous and widely scattered rather than localized at three points. Theoretically, original centers should be more numerous and important in tropical than in temperate lands, and should diminish poleward, because the total number of plant species is greatest in the tropics and diminishes gradually toward the poles. The largest number of potentially useful species would be expected in those regions of the earth where the total number of species of all kinds is greatest. Thus the fact of greatly localized centers of origin of cultivated plants is a thing in need of explanation.

The three great centers of origin of cultivated plants are also known to have been for untold centuries regions of human culture of a high order. It is beyond question that the correlation of centers of plant origin and centers of human culture is no mere accident or coincidence. Where man began his fight to live he had to depend upon the neighborhood for food. It was not for primitive man in the Levant to get rice and cotton and oranges from India, or cocoanuts, beans and potatoes from beyond the seas. We may grow in our gardens plants from almost every clime, and we may purchase in the marts such products as we cannot grow, but our earlier ancestors had no such opportunity. It was under the compelling influence of the sternest need that they sought everywhere about them for plants which might supply their needs.

When in the course of centuries our ancestral clans spread northward and westward over Europe, their problem was very different from the one that confronted their primitive ancestors

and ours. For now they had in cultivation the plants which could supply their needs. The problem before them was a much easier one, that of taking their crop plants to the new countries that they occupied. This procedure involved acclimatization, whether more or less depending upon whether the journey to the new country was long or short. That acclimatization was successful is shown by the fact that plants from the Levant and elsewhere form the mainstay of European agriculture. Had our ancestors been unable to take their economic plants with them, they would have been forced to develop new ones in their new home, or return to their native country.

If a crop plant has already been brought up to a high state of successful cultivation with many useful varieties adapted to various soils and climates, it is obviously an advantage to use that as far as possible rather than to start some new crop plant on its way from the wild ancestral form. In this way man has gone from country to country and from continent to continent, depending on what he has known rather than on what he finds. It is not strange, therefore, that under the impulse of long custom, man has become conservative and inclined toward inertia, so far as the production of new crop plants is concerned. That this inertia has been a detriment to human progress can not be doubted.

In the earlier horticultural development of the United States, it was quite natural that the familiar European varieties of the grape, the strawberry, the gooseberry, the red raspberry and other fruits should have their cultivation attempted in America. It may or may not have occasioned surprise that these attempts were unsuccessful. These early failures, however, proved blessings in disguise, for they resulted in attempts to get good American varieties from the closely related species of these plants that were native to America. It should not surprise anyone familiar with plant habits that these latter attempts proved successful, for it is one of the rather general laws of plants that successful cultivation consists largely in the approximation of natural life conditions. It should be expected that plants of American nativity would thrive better in America than plants of other nativity, because it may be assumed that through age-long experience with American conditions they have become adjusted more or less completely to their environment. However, the above horticultural varieties of European origin have proved successful in California, suggesting that

growth conditions in California may be more comparable to those of Europe than are the growth conditions in the eastern United States.

It is chiefly in the small fruits that our contribution of economic plants is at all important. Peculiarly American are the cranberry, blackberry, dewberry, black raspberry, and blueberry; valuable varieties of the grape and the red raspberry also have originated here, while the American gooseberry doubtless has important possibilities. Next in importance to small fruits among our derivatives are the nut trees. The pecan is a contribution of growing importance, and possibilities worth-while may be considered in the walnut, butternut, hickory nut and chestnut. But the smallness of our contribution to the world of economic plants is shown by the fact that we have originated no important cereal, although cereals are the most important food plants. We have given to the world no vegetables of consequence; no fruit trees of major rank, though experiments with the native plums are promising; no field crops of any importance. The fiber plants we cultivate come from somewhere else, and our supply of rubber not only comes from plants of foreign nativity, but for the supply itself we depend on other lands.

Professor Coulter has shown how the war stimulus gave us new motives, leading us to look about us and see if we could not find useful plants hitherto unnoticed. It seemed to take the war stimulus to arouse us from our lethargy along experimental lines of this interesting sort. Only when things gave out, because of diminished foreign supply, did we begin to investigate our possible assets. We sought potash, material for bandages, new sources of industrial oils, cellulose, etc. Now that we can look again to the sources of former supply, we tend to drift back into our ante-bellum sleep. This is most unfortunate, for we seemed to be on the threshold of great things when the armistice arrived. The doctrine of "safety first" requires that pioneers in a new country plant first the things that they are familiar with. Imported people must first use imported plants. But once the citizens of a new land are truly on their feet, it is time to experiment with some of the plants native to the country. It would not particularly burden any experiment station to carry on experiments with native plants, a few at a time, to seek out economic possibilities. At any given time the main work of such a station would be the experimental study

of the staple crops of the region, but together with this there should be carried on experiments on native plants. Most of these experiments might lead only to negative results, but now and then new plants of value would certainly be found; and it is never impossible that the agricultural life of a region may be revolutionized by such discoveries. Significant studies of the sort here mentioned are those on the sand-cherry in Nebraska, on the native plums in Minnesota, on the tepary-bean in Arizona, and particularly there may be mentioned the discovery of new rubber-producing plants suited to growth in our arid Southwest.

The discovery of new crop plants, admittedly of great value in war time, is of much more than academic importance in time of peace. We may think that we have a sufficient number of cereals, or vegetables, or fruits, or fiber plants, but there are two big reasons for being always on the lookout for more. First there is always the chance that we shall discover a plant that is better in some important respect than any we have known before; this would seem to be the case with guayule and some of the other new sources of rubber. Then it is always well to have an alternative. The world has long depended on flax for linen and for linseed oil. But flax is very particular as to the kind of land it likes, and its continued growth on such land results in deterioration; the land is said to become "flax-sick." This situation may be remedied in more than one way, but one of the important ways is to find some other fiber and some other oil as good as those that come from flax. The dominant political trend of the moment seems to be one that regards America as "sufficient unto itself." In the plants it cultivates it is confessedly dependent on other lands. No one can yet dream what might be yielded by an adequate study of the economic possibilities of the American flora.

THE NEW ENGLAND ASSOCIATION OF CHEMISTRY TEACHERS.

New life and vigor is now being put into this association by a few live-wires who have been connected with it for a number of years. During the past three months its membership has increased from 163 to 301, and if the members continue to work as they have been doing in the past few weeks there is no question but what the membership will be over 500 before the end of the year. Let the good work continue. The more of this work that's done, the better it is for the teaching of chemistry throughout the country.

THE NEMATODES AS TEACHING MATERIAL.

By Arthur C. Walton,
Northwestern College, Naperville, Ill.

In the course of a number of years of work on the life-histories of numerous free-living and parasitic nematodes, it has naturally been convenient to make use of the material for class demonstration, especially in the subject of embryology. The readiness with which nematode material can be adapted to class use has demonstrated itself more and more strongly each time it has been used. The ease of obtaining the material, of keeping it alive after getting it, and the numerous points of embryology which it illustrates, has caused me to use the material not only in college classes, but also to apply it to high school work.

It has been my experience, and I suppose that it has been that of all other biology teachers, that to teach the student even the simplest fundamentals of embryology has been fraught with considerable difficulty because of the lack of illustrative materials, especially in the city schools. Hen's egg material is expensive and incubators are seldom a part of our equipment. Embryos of pigs, rats, etc., which may be obtained from various supply houses, are difficult to procure, and often expensive, so we do the best that we can with frog's eggs—when obtainable—and depend mainly upon text-book figures and charts for our illustrative material. This we know is not satisfactory, and as a result many teachers slight this rather important field of a biological course, at least from the animal aspect.

The group of the round worms has come to our rescue, not only with cheap and rather easily obtainable material, but also with material which illustrates a wide variety of types of embryonic development. These worms may be divided into two main classes, (a) the free-living nematodes, and (b) the parasitic nematodes.

(a) The free-living nematode, as has been pointed out by the work of N. A. Cobb of the U. S. Department of Agriculture, is almost omnipresent in the soils of our country, whether high and dry, marshy, or completely submerged, and is often of the greatest importance from an economic viewpoint as an enemy of corn, wheat, grasses, etc. From the economic standpoint then, these free-living worms should furnish excellent material illustrating the soil enemies that the farmer must combat. Many of the cereal joint diseases, blamed onto the fly, the bug, or the beetle family, are really due to the presence of the little roundworm.

We can easily test in the laboratory for the presence of these animals in our soil. Take a little dirt, preferably from a garden plot that is not too rich in lime or ashes, and place, thoroughly moistened, in a glass-covered dish. Cut up a few small bits of raw meat—or earthworm—and spread over the surface of the soil. In three to five days—if we keep the soil damp—the decaying bits of organic material will be covered with numerous small (1-32 to 1-16 inches), white, thread-like worms. Patience is about the only outlay that is demanded of the teacher or the pupil in obtaining these round-worms. After obtaining the worms, they should be transferred to a peptone solution (chemically pure water and peptone) together with the decaying meat. The bacteria on the meat act upon the peptone solution, reducing the protein to a form that the worms can assimilate. They can not survive in a solution free from bacteria, the latter not being food, but only acting as agents to break up the peptone into a form available for assimilation.

The worms thus obtained are mature and begin to reproduce about the third day after being placed in the solution. Reproduction takes about three to five days and then the adults die off. They seldom live more than ten or twelve days after reproduction has been completed. Before the last adult has disappeared the new generation has matured and the next reproductive cycle appeared.

These forms are splendid illustrations of several types of embryonic development. The majority of the forms obtained would be hermaphroditic and of three types, the oviparous, the ovoviviparous, and the viviparous. They probably would be either *Rhabditis* or *Diplogaster* species. The animals are very transparent and show the internal organs clearly when examined under the microscope. The ovaries are generally U-shaped, and contain from six to ten eggs at one time, more being differentiated from the primordial germ cells as the older ones become matured and passed out from the body. The total number of eggs formed is between four hundred and twelve hundred, the larger number of eggs being found in the oviparous species. Of the number of eggs, seldom more than two-thirds are fertilized or capable of any development, the number of sperm formed in these species being far less than the number of ova.

In the ovoviviparous species, the greatest majority of the eggs are of the oviparous type, and only the last few are retained within the body. These give rise to from four to eight embryos

which attain practically their adult condition before they break out of the surrounding body wall of the parent, after having destroyed all of the contents. These internally developed embryos can be very clearly seen within the transparent body of the mother. Death in the adult occurs from two to four days before the active young manage to rupture the retaining body wall.

The truly viviparous species shed a large number of eggs before the four to eight embryos begin to develop internally, but these eggs are apparently unfertilized as no embryos develop from them.

Fertilization in all of these forms is internal, being mainly self-fertilization, although some cases of cross-fertilization may occur. In the latter case, the worms are protandrously hermaphroditic. About one per cent of the young will develop into males, the rest are hermaphrodites. These males apparently have lost the sexual instinct to a great degree, since copulation is seldom observed, even though the males are surrounded by hermaphroditic females. That they are not sterile forms is shown by the fact that when copulation does occur, the resulting embryos are all normal, and half are males and half females. The males are fertile, but the majority of the females develop the hermaphroditic state and generally avoid copulation with the males. The loss of the sex instinct has accompanied hermaphroditism so closely that the few incidental males are unable to restore the sex ratio of forty-eight males to fifty-two females of most nematodes through the fifty-fifty ratio which is found in the isolated cases of sexual reproduction. None of these forms are to be regarded as examples of parthenogenesis, nor of paedogenesis. For an example of parthenogenetic forms we must turn to the ants and the bees, and for paedogenetic forms, to the blood-red larvae of the *Chironomidae*. These larvae are about one-half inch long, and are found in semi-stagnant fresh water pools. The classical place to look is in an old, algae-inhabited horse trough, but never in a cement one with a flowing stream always passing through it.

(b) The parasitic round-worms offer us examples of embryological development of a different type, just as favorable for high school laboratory use as the free-living forms, but generally more difficult to obtain.

For the teacher who is near a slaughter-house, it is generally possible to obtain two species of the *Ascaridae* which are large

and easily handled as laboratory material. One form is *Ascaris megalocephala*, the round-worm of the horse—and often of the cow—and the other is the round-worm of the pig, and occasionally of man (*Ascaris lumbricoides*). A third group of Ascarids, *A. canis*, *A. felis*, and *A. triquetra*, are found in the intestines of practically every dog or cat that one might obtain for dissection purposes. Unfortunately these worms also become inhabitants of man, and it is well to warn all who use any of these three species that cleanliness is absolutely essential in avoiding infection from the eggs.[1] The enormously resistant cell wall is capable of tiding over long periods of unfavorable conditions. Important as this ability may be among the free-living forms, it is vastly more so among the parasitic species. These are largely dependent upon transferal from host to host by the ingestion of eggs, and therefore these eggs must be able to endure not only the interval between hosts, but also the action of the digestive juices of the mouth and stomach of the new host, before they can become established in the small intestine. The embryonic development is started within this resistant cell wall and continues until the embryo reaches the adult stage and is adequately protected by its own moisture-proof outer coat. When almost mature, the worm ruptures the surrounding shell of the egg and comes to lie free within the intestine of the host.

This imperviousness to external agencies is to the teacher's advantage in preparing the material for class use. There are two methods of making use of this material in the study of cell cleavage. The first is the preparation and fixation of the eggs of these worms outside of the laboratory periods, perhaps during the summer or at times when the material is available and the time not suitable for immediate use. The second is the far better and more beneficial method of placing the living embryos before the pupils, and allowing them to observe the development in the eggs from day to day. These methods of course must depend largely upon the availability of the material, as it may only be obtained at a time when it is utterly impossible to make use of it for immediate class study. Of the three types of Ascarids mentioned, the round-worm of the horse is the largest (8-14 inches), that of the pig round-worm next (5-9 inches), and those of the cats and dogs are the smallest (2-5 inches). These forms are all dioecious, but the females can be recognized by the

[1]Living Ascaridae should be handled with care. They produce secretions which are irritating to a sensitive skin, even causing temporary blindness if accidentally conveyed to the eye. —[Editor.

straight, sharply tapered posterior end, while the males have a distinctly curved, gradually tapered extremity.

The worms, when obtained, should be kept at body temperature in Normal Salt Solution until they can be used. The posterior end of the body is then clipped off and the Y-shaped ovaries and uteri are stripped out and placed in the killing and fixing solution. In case the material is for immediate class use, it may be placed in weak formol solution (2-3 per cent). The eggs are then dissected out of the uterus and may be examined from time to time under the microscope while still in the formol. If it is not possible to make use of them immediately, the various stages may be removed from the formol and placed in Carnoy's Fluid (Glacial acetic 1 part, Absolute alcohol 3 parts) for fixation. The material is then removed after an hour or so and kept in alcohol (70 per cent). Ascaris eggs will live and develop in weak formol, or the lower alcohols, for several weeks, the only apparent effect being a slowing up of the cleavage process. The resulting embryos are normal in all visible aspects.

Where class examination of the living material is possible, eggs of the one cell stage may be kept in the weak formol and watched from day to day as they develop through the various stages into a complex embryo beginning to assume a form similar to that of the adult. The cleavages are clear cut, and at first almost equal because of the absence of yolk material, but care must be used to explain that the T-shaped embryo of the four-celled stage is typical only of nematodes, and is not found commonly among other forms.

Although the advisability of the study of the maturation of the sexual elements—the egg and the sperm—in high school classes is doubtful, yet I believe that perhaps in an advanced course it may be useful. The problem of chromosomes as the bearers of sex determiners and of hereditary qualities is better omitted than wrongly emphasized, yet if we must introduce such questions, we should pick our material very carefully. The Ascarids afford some of the best, if not the very best examples for chromosome study that we have. *Ascaris megalocephala* is especially fine material. Preparation of Ascaris material for cytological purposes is rather difficult, and is beyond the equipment of the average school laboratory, if not beyond the technique of the instructor. It is better to obtain a few typical slides from some one of the numerous Biological Supply Houses and be sure of having satisfactorily prepared material. If we insist

on teaching chromosomes we must be willing to obtain the best possible material, even though it entails some slight expense.

Ascaris megalocephala is of two varieties, one having two large chromosomes, and the other, four. The variety having the four chromosomes is the more common in the United States. These chromosomes, being few in number and large and distinct, furnish splendid examples of all stages of mitosis, whether used with a microscope projector or observed under the microscope. The spindle fibers and the centrosomes are also very distinct. If the maturation of the ova is shown in the material, excellent examples of the formation of polar bodies, of the development of fertilization membranes, and of the fertilization of the ova by by amoeboid sperm are available. If cytological study of the embryos is made, the material shows the phenomenon of "diminution," or the loss of part of the nuclear material at the time of the division of the two-celled embryos. This "diminution" occurs in one of the two cells, but not in the other. The one in which the phenomenon occurs is the forerunner of the cells which make up the various portions of the adult body. The other cell is the forerunner of the germ cells, and in the sixty-four cell stage of the embryo, the descendants of this cell have isolated all the germinal possibilities in the embryo into a single cell, all of whose successors are germ cells, and germ cells only. This shows the early beginning of the differentiation of the germ elements from the soma elements, appearing in this animal as early as the four cell stage. This material furnishes excellent illustrations of the germinal continuity theory of Weismann.

If material of *A. lumbricoides* or of the ascarids of the cat or dog is used, then the number of chromosomes involved is too large for class observations, but the presence of a group of sex determining chromosomes is the point to be emphasized. The developing sperm cells show very distinctly the presence of the so-called "sex-chromosome complex" which acts as a single unit during cell division and ultimately comes to lie in only one-half of the matured sperms. The sperms which contain the "complex" bear the determiner for femaleness on fertilizing an egg, while the other type of sperm lacks this determiner for femaleness, and therefore forms a male by the fertilization of an ovum.

One further use of the Ascarid group is as material for dissection. This material is fine to use in a class in zoology such as we find in the second course of the subject. Students in their

second year of zoology are capable of the easy dissection needed to show the structures of the worm, and to understand the features that such a study should bring out. These animals show very plainly the characteristically simple digestive tract and the very complex reproductive system of a parasitic animal. The mouth, with its three smooth lips, and the muscular pharynx opening into a straight and undifferentiated stomach-intestine, are characteristic of an animal which lives upon predigested food. The intestine is thin walled and lacks muscles, and also is poorly equipt with digestive fluids. These worms also show the first appearance of a coelom as distinct from the enteron, taking the Protozoa as the starting point of development. Ascaris furnishes a nicely graded step in between the conditions as we find them in Hydra and in the earthworm. Cross-sections of *A. lumbricoides* are not worth while studying in high school classes, but for the teacher, offers some material well worth while to examine. The absence of mesoderm from the intestine walls, the absence of organized mesoderm in the body wall, the excretory system embedded in the body wall, and the dorsal and ventral nervous chains are all things that are helpful for us to know.

There are several other groups of the parasitic round-worms which, though not available or advisable for class room demonstration, are of considerable economic value and should not be omitted from a consideration of the possibilities of the nematode group as teaching material. Among these economic forms are the nematodes which cause the hook-worm disease in the poor whites of the South; the round-worm which causes measly pork, *Trichinella spiralis;* and the filaria worms. Trichinella when eaten in poorly cooked pork, hatches out in the stomach, bores out into the blood stream, and finally comes to lie in a cyst in the muscles of the body, causing a practically incurable type of rheumatism. The filaria worms get into the blood of man and cause the terrible disease known as elephantiasis, in which the arms and legs and other parts of the body become greatly swollen. These worms are found in the tropics only, and are supposed to be transferred from host to host by certain kinds of mosquitoes. The Guinea worm of Africa gets into the muscles of the lower limbs via the intestine, and after sexual maturity, the females migrate into the feet. Here the head is pushed through the skin and the eggs are released into the outside world. The sores formed by the breaking of the skin in this manner are extremely difficult to heal. The female often attains the length of thirty-

five to forty inches, and causes severe pains to extend throughout the entire length of the limb infected.

These few examples of the use to which the Nematode Group may be put in high school work are simply suggestions of the possibilities of these interesting animals. Perhaps they may seem to be stressed too heavily, yet the suggestions are presented as material which actually has been made use of at various times in teaching students of high school grade, and which has accomplished the desired end of being workable and successful illustrations of some of the most difficult and too often slighted parts of our biological subject matter.

All of the above material can never be used by any one class during a single course, but there is enough presented so that the teacher may be able to make selections to fit his needs. Some of the material is not usable in laboratories that are not very completely equipped, yet I believe that every teacher has the equipment to at least study the most of the suggested applications for his own benefit. My experience with many of our Biology teachers, and also in the training of future teachers, is that they fail to recognize even the very obvious possibilities of the various animal groups as class demonstration or class illustrative material.

In presenting this material I hope that it may be of benefit to all teachers of biology to some degree, and to some, I hope that it may open up an entirely new field of illustrative forms, and thus lighten in some slight degree the task of finding laboratory demonstrations suitable for high school classes.

CLASSROOM SAYINGS.

A vitamine is something you can't see or feel but it is there.

Adiabatic heating is heat without fire, as a fireless cooker.

The human body is composed of the head, the drunk and the limbs.

The kidneys are used to digest the juices of the blood.

Flies, mosquitoes, flee all carry diseases and must be illuminated.

When they tried to raize figs in California they were troubled with rats. This was overcame by raising bats.

COPPER MINING IN THE CHITINA VALLEY, ALASKA.

The copper mines of the Chitina Valley are the largest and richest thus far developed in Alaska. Their successful development has been made possible by the completion of the Copper River & Northwestern Railroad, which affords transportation to tidewater. The recent mining progress in this district is shown in a report entitled "Mining in the Chitina Valley, Alaska," by F. H. Moffit, issued by the United States Geological Survey, Department of the Interior, as Bulletin 714-C.

THE USE OF THE TEXT-BOOK IN BEGINNING CLASSES IN BOTANY.

By Arthur M. Johnson,

University of Minnesota, Minneapolis.

I am frequently asked by prospective teachers, if I favor the use of the text-book in beginning classes in Botany. My answer has always been in the affirmative. It seems to me that if there is any subject in the high school curriculum in the teaching of which the text-book is essential it is botany.

The subject of botany may be pursued in several different ways, and there is in consequence little uniformity in the teaching of it. Too often, perhaps, the course of study has been made dependent on the text-book in use, and the choice of a text-book has depended upon the individual likes and abilities of the teacher. In cases, therefore, where the text-book in use has been regarded as "unsatisfactory" or too "difficult" the course of study and the teaching have suffered. In some cases where teachers of ability have worked out a course of study suited to local conditions the text-book has been discarded altogether.

I believe, however, that the text-book has an important place and function in the beginning course. Therefore, I should like to point out in the following pages certain fundamentals that have a bearing on the text-book in relation to the beginning course in botany.

Let us see what these fundamentals are. In the first place, in teaching an elementary course, we have to consider the type of course of study. As we know, there are several types of courses being taught in our high schools. There are, for example, the old "herbalist" type of course, the "type" course, the "dynamic" course, and the "synthetic" course, and in some quarters we hear about a "practical" course. Each one of these types possesses more or less merit, much depending on how it is taught. A teacher may adopt any one or a combination of these types of courses or follow a hit-or-miss procedure, devoid of any plan or conformity to a type. It goes without saying that the type of course we adopt bears an important relation to our teaching of the subject.

Having decided upon the type of course, our next consideration should be the nature of its content. That is the second fundamental. What shall we include in our course of study? That is the question. It is required that we distinguish clearly between essentials and nonessentials, and have an understanding

of fundamentals. For example, if we have decided upon a "type" course it will be important that we understand the selection of "type" forms for study, and know what groups are representative. This will be appreciated in considering such groups as the algae, the fungi, and the flowering plants. In the latter group shall we choose a highly specialized or a less specialized flower as the "type"?

Our last consideration is the organization and correlation of the subject matter of the course of study. This, too, is fundamental, and one of the most important matters in the teaching of the science. How to assemble, systematize, and correlate the content of our course so that the facts and phenomena about which we teach shall be brought into their proper relations, that is a matter to which we should devote serious thought. Facts in themselves may be interesting, but unless they be shown to have some connection with other facts or some relation to life in general, they are meaningless. A study of mere facts, unorganized and unrelated, resolves itself into desultory routine.

It is in connection with the fundamentals discussed above that the text-book should subserve a useful purpose as guide to the teacher. The text-book speaks with the weight of authority; it reflects the views and ideals of its author, not only in matters of content and point of view of the botanist, but also in the matter of pedagogical presentation; it is the product of the author's long experience. As such it is worthy of consideration.

There is no modern text-book written, however, which will suit all teachers and all conditions. On the other hand, there is a sufficient variety of text-books on the market to enable teachers to make a suitable choice. But there is much to be said about choosing a text-book, one which shall meet the "requirements" of the teacher, the principal, or the superintendent. The usual "requirements" are that the text-book shall be "easy," not "too difficult," "practical," and so forth. I have never had it clearly explained to me just what is meant by an "easy," a not "too difficult," and a "practical" text-book on botany I do not believe an "easy" text-book on botany can be written and still be dignified by the name of text-book. The demand for an "easy" text-book, it seems to me, is but an apology for ignorance.

The usual procedure in selecting botanies is to adopt a text-book and then flounder about in an effort to get the "material described in the text-book." Nothing whatever is done to make

a study of the local environment, in order to determine first what sort of botany would be best-suited to those conditions; and nothing is done to construct a course of study based on those conditions, after which a text-book may be selected which shall best conform to those conditions. Fit the text-book to the course, and not the course to the text-book. If teachers, principals, and superintendents would give more thought to the matter just mentioned and to the type of course of study, there would be less impatience, I think, with our text-books. If a "dynamic" type of course be adopted for example, a course based primarily on physiology, it is obvious that a text-book whose underlying principle is morphology would fail to meet the "requirements." Likewise a text-book based on physiology would be a failure in a course based on morphology, and with a teacher who knows nothing of physiology. And what success would a teacher unversed in ecology have with a text-book dealing almost entirely with plant relations? And what shall we do with plant pathology, plant diseases, plant genetics, mendelism, etc.? There is scarcely a text-book today but that which treats of these subjects. Shall we regard these books as "too difficult," and yet put in a "requirement" that the text-book shall be "practical"? Shall we discard such text-books? Rather should we not devote a good deal of time to the study of these books? Should we not, as teachers, follow carefully the trend of education in our subject?

There is another element of not a little educational value in connection with the text-book which I think is worth our consideration. That is the general make-up of the book. Without exception, I think, our modern text-books on elementary botany are models of the book-maker's art. In pictorial presentation alone, they are unexcelled. For these reasons and because of the nature of the subject, they possess a peculiar appeal. There is an inherent quality in the study of plants which authors and publishers alike have been quick to recognize the importance of, and which lends itself peculiarly to the training of the finer instincts. That is the quality of beauty. Take any modern text-book on botany we like, and likewise text-books on agronomy and agriculture, and we can not fail to note in them a preponderant appeal to the beautiful. It may be said that any text-book which fails to recognize the value in education of the element of beauty will fail of its mission. The world of business long ago appreciated the psychological value of the beautiful.

A glance at the advertising columns of our magazines should convince the skeptical. The automobile advertisements are excellent examples. Studied beauty of design may be noted in every tool, every machine we use. "The omnipresence of beauty is finished and normal living things must have some meaning, and even if it only means that something in us responds pleasurably to what nature mints and fashions, that is a fact of great significance" says J. Arthur Thomson in his charming book, The Bible of Nature. Now if plants, the woodland, the field, the prairie, are things of beauty, and if the appeal of the beautiful is of any value in education, should we not seize upon them as means to an end? I venture the thought that botany is intrinsically a cultural subject. That ought to be a fact of great significance. Should not training for citizenship, which we hear so much about of late, involve some element of cultural value? What subject in the curriculum is, by the very nature of its materials, so well adapted to cultural training as botany?

Now, if books have any place in education, if training in appreciation through books has any meaning at all, if contact with and taste for good books play any part at all in the making of better men and women of our children, what more stimulating ones can we find than our present text-books on elementary botany? What means to these ends have they to offer in their place who discard them? A few years ago a young foreigner came into my office and in the course of his visit took one of our elementary botanies from my desk and proceeded to examine it with great interest. "What a wonderful book that is" said he. "How beautiful! We do not have such text-books in my country. What an inspiration it must be to your students!" Inspiration! Indeed. I have often wondered, since the above remark was made, whether we have a right to deprive our students of the companionship of a good text-book.

While I have no data on which to base an opinion, I believe, however, that the best teachers of this country, in our colleges and universities, at least, those who by their training and experience know most about the subject, and who have also devoted years to the study of the pedagogy of the subject, are using the text-book in their classes. I believe their judgment is sound and their leadership worth following.

It should, therefore, be the duty of every teacher of elementary botany to study carefully the text-book; learn the system of the book. "Till you understand its system," says Dr. Fernald, "a

book is never all your own." "Learn the geography of your book." "Apply a little intelligence to the mechanism." I would add, that in respect to the text-book of Botany, we read the preface; get at the author's point of view; study the table of contents; get hold of the subject-matter of the book and its organization. Study the language of the author and follow his development of some particular subject. Learn his treatment of essentials and fundamentals. Get the significance and application of the illustrations.

One of the most profitable pursuits that I know of in this connection is to make a comparative study of different text-books, topic for topic, from preface to index. We shall be abundantly rewarded for the time thus spent. It will acquaint us with the points of view of the different authors and awaken us to the possibilities of different methods of presentation. In this way, too, we may at least come to know our text-books, which is not the least valuable factor in our progress. The great danger in the abolition of the text-book is that teachers shall become static. Once contact with the text-book is definitely cut off all interest in anything new to the science and to the teaching of it is lost; there is a drift out of the main current of progress into slowly eddying shallows where the materials of knowledge accumulated soon settle into the gloom of stagnation. Were the abolition of the text-book compensated for by any propensity to study directly and systematically the phenomena of Nature and to keep abreast of progress in the science I should less object to the plan. But in general such a condition does not exist. The text-book is and will continue to be the only source on which the average teacher will rely for information on the progress and the teaching of the science.

HUMAN GEOGRAPHY TEXTS.

By W. M. Gregory.

The texts named below are new material that greatly enrich the entire field of geography. One cannot help wondering why the human element in geography has been so slow in developing in this country. Geography in the United States has drawn its material largely from the natural sciences which have contributed formal statements of principles of but little relation to human elements. Astronomy, geology and physical geography have burdened nearly all phases of geography with their condensed statements and formal principles. The human elements have received scant attention and have long been neglected.

Human Geography, Brunhes; Rand McNally & Co.

Principles of Human Geography, Huntington and Cushing; John Wiley & Son.

Manufacturing Industries in America, Keir; Ronald Press.
World Power and Evolution, Huntington; Yale University Press.
Coal, Iron and War, Eckel; Henry Holtz & Co.

Geography, in modern education recognizes the human element and this aspect will receive greater emphasis as the material is organized. In the curriculum of secondary and elementary schools human geography is receiving a constantly increasing emphasis. The old material borrowed from geology, physical geography and astronomy appears in comparatively few of the modern tests for school use.

The material of the above texts will be especially stimulating to secondary school geography teachers. The newer courses in secondary geography emphasize the relationship existing between the activities of man and the simple geographical controls. The geographical responses as shown in man's activity are abundantly illustrated in these books.

Huntington is the leader of the school of human geographers in this country. His contributions are stimulating and of special value to those interested in the problem of geography teaching. Huntington's efforts to prove the changes of climate have resulted in a collection of material related to human geography, which is unique and remarkable for its simplicity. A study of Huntington's works will give added interest to students of geography who desire to see it a real study of mankind.

The above books are pioneers in human geography. They will lead to a revival of geography in the high schools that will be different in character than the specialized physical geography which emphasized the physical elements. Human geography will make its appeal to pupils who are preparing to study social sciences and it will serve as a basis for history, economics and commercial studies in trade and industry.

The geography in the senior and junior high schools is unorganized and without a unifying influence. The large part that foreign trade now plays in the United States, the new phases of development in industry, the many new industries are all without adequate presentation in the most modern of our commercial geographies. Many aspects of economics and history which have their explanation in geography are not available in textbook form. The term "human geography" is a logical center, around which much of the modern material for industry, commerce and trade may be collected. The above texts are an indication of what may be expected in the future growth of geography.

ILLINOIS STATE ACADEMY OF SCIENCE, FOURTEENTH ANNUAL MEETING, CARBONDALE, APRIL 29-30, 1921.

Dr. Shryock, president of the Southern Illinois State Normal welcomed the Academy to Carbondale and President Cowles responded.

The acting Secretary gave some facts concerning the publication of three volumes of Transactions and reported that the volumes had been mailed to all members.

The Treasurer's report showed a balance of $704.23, the largest in the history of the Academy.

Reports were made by Prof. Cowles for the committee on Ecological Survey and the committee on Legislation. Prof. Barber reported for the committee on Secondary School Science and Prof. Knipp for the committee on High School Science Clubs. Prof. Van Cleave for the committee on Membership read a list of 149 names of candidates, the largest list presented at an annual meeting.

After the business meeting the Academy adjourned to the fine chapel room where seated upon the platform, after very happy remarks by the

presidents of the school and of the Academy, the members were introduced to the nine hundred students present. Each member arose and stated his name, place of residence and occupation, furnishing a fine illustration of the fact that all parts of the State and a great variety of sciences are represented in the Academy. Each was greeted with applause.

After an excellent luncheon together in Anthony Hall, the invitation addresses were delivered in Zetetic Hall on the general subject of nature and man in southern Illinois.

A delightful banquet preceded the evening address by the retiring President—an illustrated lecture on the state park movement. The audience which comfortably filled the auditorium of the church greatly appreciated the lecture.

Two days of interesting excursions followed the papers—an innovation with our Academy.

The weather was favorable, the physiographical, geological, botanical and zoological features were interesting.

The citizens of Murphysboro conveyed the company in automobiles to Fountain Bluff and after several hours tramping over the hills the company were in proper condition to enjoy the barbecue so hospitably prepared.

The excursion taken to Fern Cliff the following day will long be remembered because of the many interesting scientific and scenic features and the hospitality of our hosts.

A cordial invitation was received from the president and scientific faculty of Rockford College to hold the next meeting in Rockford.

Throughout the meeting there were many expressions of appreciation at the happy way in which the presiding officer handled situations indoors and out, and also regret that the Treasurer who had been serving the Academy so skillfully for the last years did not see his way clear to continue in office.

New Officers for the year 1921-1922: President, Charles T. Knipp, Urbana; Vice President, Miss Ruth Marshall, Rockford; Secretary, C. Frank Phipps, DeKalb; Treasurer, W. F. Schultz, Urbana.—[A. R. Crook, Secretary.

OPEN WINTER AND PLANT LIFE.

An open winter, such as is being experienced in this locality this year, is generally more injurious to plant life than it is beneficial, in the opinion of Dr. John W. Harshberger, professor of botany at the University of Pennsylvania.

Certain plants, according to Dr. Harshberger, have been so protected and planned by nature that they are unaffected by such unusual weather and in other cases no definite harm is done unless the warm period lasts a long time.

Warm weather in winter is not especially injurious to plant life unless it starts dormant buds to swell and burst open, thus exposing the delicate leaf and flower tissues to the action of the succeeding cold spell.

There are many native plants, trees, and shrubs which are not ordinarily stimulated to development by warmth in the winter season because they have been long adjusted to the particular climatic conditions of eastern North America. Meteorologists tell us that this exceptional weather has had a counterpart in the past, and as our native plants have existed for many thousands of years, there is no doubt but that they have many times been exposed to conditions to be found to-day.

Then there are many plants which normally blossom early in the year before actual spring conditions come. In this category are the skunk cabbage, the witch hazel, and the like. These plants are not especially injured by periods of cold weather succeeding an open winter.

In addition, there are a few plants introduced from Europe and other countries, such as the Japanese witch hazel, the snowdrop, the winter aconite, and the Christmas hellebore and others, which frequently flower in January succeeding a few days of open, warm weather. When this warm spell is in turn followed by snow, the winter aconite and the rest of these garden species are completely covered up, and when that snow melts they are found to be uninjured.

Snow is a good protection to plants. In fact, snow is one of the best protections that plant life has against the rigors of winter. A cold, snowless winter, with high winds and low temperature, is much more destructive, generally speaking, to plant life than a winter with a heavy snowfall. This ability of the snow to act as a blanket for plants has been repeatedly shown in the north of Italy, where an early spring snowfall will do less damage to crops than a late, snowless period of cold weather accompanied by high winds and bright sunlight.

During the early months of 1920 there was a very interesting exemplification of the action of a frozen soil and cold weather. The soil was frozen to the depth of more than a foot and later a heavy snowfall came, which partly melted and was again frozen to form an icy sheet several inches thick. This was followed by an extremely cold spell with strong winds and bright sunlight, which, however, was counteracted by the blanket of snow and ice.

It is a fact, however, that hardly any season in the annals of Philadelphia horticulture has been more trying and detrimental to conifers, rhododendrons, and other evergreens than was last season. Rhododendrons were destroyed by thousands where gardeners had not had the forethought to cover the roots with a heavy mulch of forest leaves and other litter. The reason for this destructive action was the fact that during the winter rhododendrons and kindred species are constantly giving off considerable amounts of moisture, and this loss of water from the surface of the plant is increased by bright sunlight and strong winds. The water thus given off during an ordinary winter is obtained from the soil, but in 1920 the soil was frozen to such a depth that the roots were unable to obtain the water necessary to replenish the loss from the surface and consequently the plants dried up, their leaves turning brown and withering, with a result as disastrous to the tops of the plants as a fire would have been.

Many plants get rest in winter. The period of winter is advantageous to many plants, which enter a period of rest at this time, giving an opportunity for the ripening of the wood and the maturing of the buds. This has a beneficial result on the gradual preparation of the underground part of the plants for the burst of spring growth. In fact, some bulbs and some seeds will not begin growth until they have been subjected to either the cold of winter or the drought of such climates as we find in the great deserts.

This feature is known as the "rest period," and for this reason an open winter, in giving no such opportunity, is sometimes succeeded by a less vigorous growth the following spring, as contrasted with a winter of abundant snowfalls and normally low temperatures, which produce the necessary ripening effect on buds and other dormant parts of the plant.

A cold spell is particularly dangerous to plant life after a period of

warm rains with open grounds, because most plants absorb water during the winter and become gorged in their overground parts. A subsequent freezing is liable to burst the delicate tissues of the plants. Frost cracks on trees are a good example of this danger, and they are quite likely to result, particularly if the cold spell is followed by bright sunlight. Without the latter the water which is frozen out of the plant tissues may be absorbed back again so slowly into the living cells of that plant that the destructive action is prevented; but with bright sunlight the ice is expanded within the plant, resulting in the aforementioned rupture of plant tissues.

For this reason, in the protection of delicate plants it is more important frequently to protect them from the sunlight in winter than from the cold weather.

Plants are safe if the buds are closed. The danger of frost in the spring or in any open spell of weather during the winter months is largely due to the influence which heat has in expanding buds and starting dormant parts of plant life into activity. As long as buds remain closed there is ordinarily little cause for worry from succeeding cold weather, but if the warm period is of long enough duration to cause the buds to expand the following cold weather generally destroys the delicate parts within, which are then no longer protected by the bud scales. The latter are provided by nature with cork, resin, or cottony or silky hairs to offer resistance to the action of the climate.

The most destructive action in buds is the entrance of water between the bud scales, for this expands in freezing and tears the frail parts of the plants to pieces. The presence of the resin and other of nature's aids helps prevent this state of affairs.

On the other hand, it is equally true that the presence of frost and ice is very beneficial to the soil in which many plants are found, because it tends to pulverize the larger soil particles through the expansion of the ice particles. As a consequence, soil exposed to the action of frost is mellowed and made fit for the growth of subsequent crops.

A final destructive effect of an open winter as contrasted with a normal one is the fact that many plants are stimulated unduly, thus shortening their lives, because the reserve foods are used up before the rapid demand of the plant comes for the expenditure of such stored materials.—[*Philadelphia Ledger and Monthly Weather Review.*

INLAND EMPIRE TEACHERS ASSOCIATION.

At the annual meeting in Spokane the last of March the Mathematics Section of the Inland Empire Teachers' Association was reorganized as the Inland Empire Council of Teachers of Mathematics, with the intention of affiliating more closely with the National Council of Teachers of Mathematics.

Professor Walter C. Eells of Whitman College, Walla Walla, Washington, was chosen first President of the new organization and Miss Jessie Oldt of North Central High School, Spokane, Washington, Secretary.

The greater part of the meeting was devoted to a discussion of the report on College Entrance Requirements in Mathematics of the National Committee. The sentiment of the teachers present was very favorable to the general features of this report.

PROBLEM DEPARTMENT.

Conducted by J. A. Nyberg.

Hyde Park High School, Chicago.

This department aims to provide problems of varying degrees of difficulty which will interest anyone engaged in the study of mathematics.

All readers are invited to propose problems and solve problems here proposed. Problems and solutions will be credited to their authors. Each solution, or proposed problem, sent to the Editor should have the author's name introducing the problem or solution *as on the following pages.*

The Editor of the department desires to serve its readers by making it interesting and helpful to them. If you have any suggestion to make, mail it to him. Address all communications to J. A. Nyberg, 1044 E. Marquette Road, Chicago.

LATE SOLUTIONS.

683, 685. *Frank G. Bruner, Black River Falls, Wisconsin.*

686. *R. Neary and H. Ruzicki, St. Martins College, Lacey, Washington; Walter R. Warne, Pennsylvania State College, State College, Pennsylvania.*

690. *Frank H. Wheat, North East H. S., Kansas City, Missouri.*

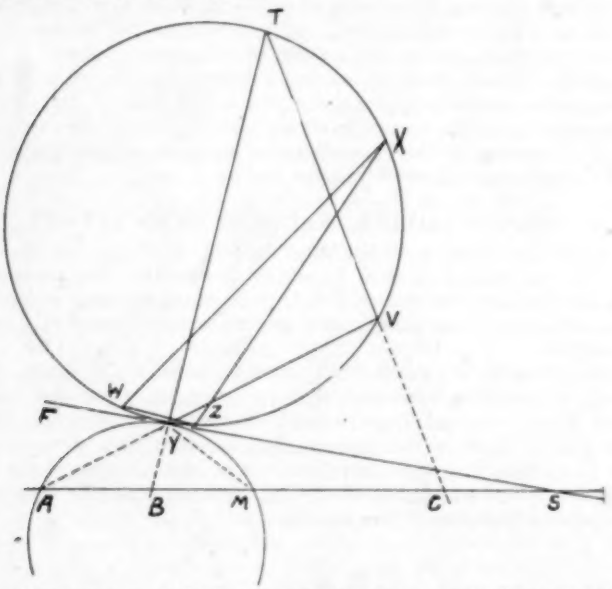
SOLUTION OF PROBLEMS.

667. *Proposed by Abigail Glenn, Chicago Normal College.*

Through three given points in the same straight line, construct three lines which shall form a triangle inscribed in a given circle.

I. *Solution by Elmer Schuyler, Bay Ridge H. S., Brooklyn, N. Y.*

Let A, B, C be the given points. Draw any line through B intersecting the given circle O in points D and E. Construct a circle through D, E, C, intersecting AC in M. Construct any circle through A and M intersecting the given circle in points I and K. Produce IK to intersect AC in S. Draw tangents SX and SY to the given circle O. Let AY intersect the given circle again at V, and CV intersect it at T. Then $\triangle YTV$ is one solution. Let AX cut the given circle again at W, and CW cut it at Z; then $\triangle XZW$ is another solution.



Proof. Construct a circle L passing through A and M and tangent to the given circle O. SY will be their common tangent since $SY^2 = SI \cdot SK = SA \cdot SM$. Since T is on BY and V on AY, we need to prove that TVC

is a straight line. Extend TV and if it does not pass through C, let it intersect the given line in C^1. $\angle BMY = \angle FYA = \angle VYS = \angle YTV$. Hence $\triangle s$ BMY and BC^1T are similar, and $BY \cdot BT = BM \cdot BC^1$. But M was the intersecting point of AC and a circle through D, E, C. Hence $BM \cdot BC = BD \cdot BE = BY \cdot BT$. Therefore $BC = BC^1$ or C and C^1 coincide.

II. *Solution by A. Pelletier, Ecole Polytechnique, Montreal, Canada.*

Let A, B, C be the three given points; from B, draw BT, tangent to the given circle; select D on BC so that $BD \cdot BC = BT^2$; from D draw DT^1 tangent to the circle, and take E on AD so that $DE \cdot DA = DT'^2$; from E, draw ET'' tangent to the circle and the chord T''N parallel to AC. Join CN and produce to cut the circle again at M; join MB cutting the circle at P. MNP is the required triangle.

Proof. Join PD and PT''. Because $BD \cdot BC = BT^2 = BP \cdot BM$, the $\triangle s$ BCM and BPD are similar, and $\angle BPD = \angle BCM = \angle MNT'' = \angle MPT''$; hence DP and PT'' are on a line. Join AP. Because $DE \cdot DA = DT''^2 = DP \cdot DT''$, the $\triangle s$ APD and DET'' are similar, and $\angle APD = \angle DET'' = \angle NPT''$; hence AP and PN are on a line.

III. The names of many noted mathematicians are associated with this problem and its generalizations. *Cajori, History of Mathematics*, page 176: "The first important exercise solved by Descartes in his Geometrie is the problem of Pappus; viz.: Given several straight lines in a plane, to find the locus of a point such that the perpendiculars, or more generally, straight lines at given angles, drawn from the point to the given lines, shall satisfy the condition that the product of certain of them shall be in a given ratio to the product of the rest." *Nouvelles Annales*, 1844, page 464: Pappus solved the problem as stated in this exercise. Gabriel Cramer (1704-1752) generalized the problem for any position of A, B, C, and this was solved by Castillon (1709-1791) in 1776, and also by Lagrange.

Pappus was born about 340, A. D., in Alexandria, and was the first to find the focus of a parabola.

684. *Proposed by F. A. Cadwell, St. Paul, Minneapolis.*

Construct a triangle, having given the base c, $\angle B$ (greater than $\angle A$), and $d = AC - BC$.

In a solution of this problem in the April copy, some letters A and B unfortunately became interchanged. The correct construction as given by *Michael Goldberg* is:

With A as a center and d as a radius draw a circle. Make $\angle ABR = \angle B$; and with any point P, on BR, as a center and BP as a radius draw a circle intersecting the first circle in F and H. Call E the intersection point of FH and a tangent at B to the circle with center P. Draw EG tangent to the circle with center A. The line AG extended is the third side of the desired triangle.

Last month a third solution to this problem was given. And now the *Proposer* has found a fourth one:

With A as a center, and d as a radius, describe a circle. Make $\angle ABR = \angle B$. Through A draw a line parallel to BR and cutting the circle at E (on the same side of BA that R is). Draw BE intersecting the circle at G. This is the same point G found in *Michael Goldberg's* construction. AG extended is the third side of the triangle. Proof: $\angle RBG = \angle GED = \angle EGD = \angle CGB$. Hence $CG = CB$, and $AC - BC = AC - CG = GA = d$.

691. *Proposed by H. E. A. Lazott, Nashua, New Hampshire.*

Divide a line harmonically, using only a straight edge.

Solution by Ethel E. Barnebey, Twin Falls High School, Idaho.

Let CF be the given line. Construct a quadrilateral ABDE, with two opposite sides passing through F, and the other two sides passing through C. Let AD and EB intersect the given line at M, and N respectively. Then M and N divide FC harmonically.

Proof. Draw CV parallel to AF, (V is on the line EN). Then from the similar triangles, we have $AB/BC = EB/BV$; $CN/NF = NV/NE$; $CV/EA = BV/BE$; $FE/CV = EN/VN$. The product of these equations gives

(1) $AB \cdot CN \cdot FE = BC \cdot NF \cdot EA$

Draw XFL parallel to AC (X is on EN, and L on AM), and

(2) $AB \cdot CM \cdot FE = BC \cdot MF \cdot EA$

Dividing these two equations, and interchanging the means we have $CN/NF = CM/MF$.

Similarly solved by *Gabriel Rousseau, student, Ecole Polytechnique, Montreal*, the proof being stated in a single sentence: ABCDEF is a complete quadrilateral, and any diagonal of a complete quadrilateral is cut harmonically by the other two diagonals; and by *Michael Goldberg, Philadelphia, Pa.*, who proved equation (2) by using the theorem of Ceva (Problem 677), ACF being the triangle and D the interior point.

Equation (1) can be derived by using the theorem of Menelaus (See solution of problem 660), ACF being the triangle, and NBE the transversal.

692. *Proposed by W. T. Harlow, Portland, Oregon.*

The vertices of a triangle are respectively 3, 4, and 5 feet from the center of the inscribed circle. Find the radius of the circle.

I. *Solution by Thos. G. Brown, Boys Technical High School, Milwaukee, Wis.*

Draw lines from the vertices to the center of the triangle. Denote the half angles by x, y, z, and the radius by r. Using the relation $\sin^2 x + \sin^2 y + \sin^2 z = 1 - 2\sin x \sin y \sin z$, we have

$$r^2/9 + r^2/16 + r^2/25 = 1 - 2r^3/60$$

or $120r^3 + 769r^2 - 3600 = 0$, whence $r = 1.9002$.

II. *Solution by Moe Buchmann, Brooklyn Evening High School.*

$\sin x = r/3$; $\sin y = r/5$; $\sin z = r/4$. And $\sin z = \cos(x+y) = \cos x \cos y - \sin x \sin y$. Substitution of the various values for the functions leads to the same equation as above.

III. *Solution by Norman Anning, Ann Arbor, Mich.*

If ABC is the triangle, D the center of the circle, AD = 3, BD = 4, CD = 5; call $s-a = l$, $s-b = m$, $s-c = n$. Then r must satisfy the four simultaneous equations $r^2+l^2 = 9$, $r^2+m^2 = 16$, $r^2+n^2 = 25$, and $r^2(l+m+n) = lmn$. Elimination of l, m, n yields $r^6 - (769/120)^2 r^4 + 384.5r^2 - 900 = 0$. This cubic in r^2 has one positive root, $r^2 = 3.60952$, $r = 1.900$.

693. *Proposed by Herbert C. Whitaker, Philadelphia, Pa.*

The sides of a triangle are 4, 5, and 6; in each angle of the triangle a circle is drawn tangent to the two sides of the angle and also tangent externally to the other two circles. Find the radii of the three circles.

Solution by Gabriel Rousseau.

Let ABC be the given triangle, $a = 4$, $b = 5$, $c = 6$; let a^1, b^1, c^1 be the distances from A, B, C to the center of the inscribed circle, and x, y, z be the radii of the circles in the angles A, B, C respectively. Then the theorem of *Malfatti* gives the following solutions:

$x = r(s-r+a^1-b^1-c^1)/2(s-a) = .96197$; $y = r(s-r-a^1+b^1-c^1)/2(s-b) = .86355$; $z = r(s-r-a^1-b^1+c^1)/2(s-c) = .70861$.

By a study of the geometry of the figure and the half-angle formulae, *Moe Buchman* found three simultaneous quadratic equations in x, y, z, but it is doubtful if they can be solved.

Inasmuch as this is one of the famous problems of gemoetry (proposed and solved by Malfatti in 1803), the editor suggests it for future consideration, in particular for those who will have access to a library during the summer. Numerous references will be found in *The American Mathematical Monthly*, March, 1917, page 126 and June, 1917, page 289.

694. *Proposed by Walter R. Warne.*

Show that $4\sin 9^\circ = (3+\sqrt{5})^{\frac{1}{2}} - (5-\sqrt{5})^{\frac{1}{2}}$.

Solution by C. E. Githens, Wheeling, West Virginia.

From a study of the inscribed decagon, we find $\sin 18^\circ = (\sqrt{5}-1)/4$; hence $\cos 18^\circ = (10+2\sqrt{5})^{\frac{1}{2}}/4$; then $4\sin 9^\circ = \sqrt{(1-\cos 18^\circ)/2} = [8 - 2(10+2\sqrt{5})^{\frac{1}{2}}]^{\frac{1}{2}}$.

Let

$[8-2(10+2\sqrt{5})^{\frac{1}{2}}]^{\frac{1}{2}} = \sqrt{x} - \sqrt{y}$; $[8+2(10+2\sqrt{5})^{\frac{1}{2}}]^{\frac{1}{2}} = \sqrt{x} + \sqrt{y}$. Then $x - y = (24-8\sqrt{5})^{\frac{1}{2}} = -2+2\sqrt{5}$; or $x = y - 2 + 2\sqrt{5}$.

The Central Association of Science and Mathematics Teachers:

The next meeting will be held at the Soldan High School, St. Louis, on Friday and Saturday, November 24 and 25, 1921.

The officers of your Association, the officers of your sections, and the committee on local arrangements at St. Louis are doing all they can to make the meeting a success. Excellent programs for some of the sections and for the general association are already in sight.

What YOU Can Do

(*a.*) Make certain that you have paid your dues ($3.00) for 1920-1921. Treasurer, Mr. L. L. Hall, Morgan Park H. S., 11043 Hermosa Ave., Chicago.

(*b.*) Pay your dues for 1921-1922, promptly. The treasurer is authorized to accept $2.50 as dues for 1921-1922.

(*c.*) Get one *or more* new members. We need them. More important—*they need us.* They will get "their money's worth" from "School Science and Mathematics" alone.

(*d.*) Persuade the principal of your school to take out a *school* membership ($2.50). How can he spend $2.50 for the school library to greater advantage? "School Science and Mathematics" will come regularly and can be read by pupils as well as by the teachers who should but will not join the association. Point out that it is the only magazine which offers constructive guidance to teachers of *science and mathematics;* that it will be a stimulating force which will pay large dividends on the investment. If funds permit, the association will doubtless resume the printing of its Proceedings, and a copy of this document also will be received by the school.

Let us prove that the members of this association can all do their part in spite of the adage that "what is everybody's business is no one's business."

W. W. HART,
President of the Association.

$\sqrt{x}-\sqrt{y} = (y-2+2\sqrt{5})^{\frac{1}{2}}-\sqrt{y} = [8-2(10+2\sqrt{5})^{\frac{1}{2}}]^{\frac{1}{2}}$.

$2y-2+2\sqrt{5}-2(y^2-2y+2y\sqrt{5})^{\frac{1}{2}} = 8-2(10+2\sqrt{5})^{\frac{1}{2}}$. This equation will be satisfied if both $2y-2+2\sqrt{5} = 8$ and $y^2-2y+2y\sqrt{5} = 10+2\sqrt{5}$ can be satisfied. This is done by $y = 5-\sqrt{5}$. Hence $x = 3+\sqrt{5}$.

The above solution was selected for printing because it is a very good illustration of a method for finding the square root of an irrational quantity. *T. E. N. Eaton, Redlands H. S., Cal.*, found the square root by solving $x^2+y^2 = 8$, $2xy = 2(10+2\sqrt{5})^{\frac{1}{2}}$. *Fred A. Lewis, University, Alabama*, used the relation $\sin 9° = \sin(45-36)$ and the functions of 36° which can be found by solving the equation $\sin 2\theta = \sin 3\theta$. Several solutions were based on the relation $2\sin 9° = (1+\sin 18°)^{\frac{1}{2}}-(1-\sin 18°)^{\frac{1}{2}}$; putting $4\sin 18° = \sqrt{5}-1$ gives the result at once. Also solved by *N. Anning; Thomas G. Brown; Moe Buchman; Michael Goldberg; Lois C. Ketcham, Chester, Virginia; Theodore S. Kimball, student, Nashua High School, N. H.; Gabriel Rousseau; and the Proposer.*

695. *For Undergraduates. Proposed by Herbert C. Whitaker.*

From a point outside an equilateral triangular field, the distances to the corners are 30, 39, and 62 feet respectively. What is the field's area?

Solution by Gabriel Rousseau.

Let OA = 39, OB = 62, OC = 30. Draw $\angle DBA = \angle OBC$, and DB = BO. Join DO and DA. $\triangle OBD$ is equilateral and AD = OC. From $\triangle AOD$ whose sides are 30, 39, 62 we find $\angle AOD = 22°36'$, so that $\angle AOB = 37°24'$. From the $\triangle AOB$ for which AD = 39, $\angle AOB = 37°24'$, and OB = 62, we find $a^2 = 1423.8$, and the desired area is 616.5.

Several incorrect solutions received, one of which is particularly interesting. If E is the midpoint of AO, and F the midpoint of BC, then if we apply the theorem: the sum of the squares of two sides of a triangle equals twice the square of one-half the third side, plus twice the square of the median to that third side, to $\triangle AFO$ and $\triangle BOC$, we get $20F^2 = 2421-a^2/2$ and $EF^2 = 2a^2-2846$. It would seem that we could now find a by applying to ABOC the theorem: the sum of the squares of the sides of a quadrilateral equals the sum of the squares of the two diagonals, plus four times the square of the line (EF) joining the midpoints of the diagonals. But this equation for a is an identity showing that the theorem is in fact a corollary from the first one. A general solution of the problem is: If the distances of O from A, B, C are x, y, z; and if K is the area of the triangle whose sides are x, y, z, then $a^2 = -2K\sqrt{3}+(x^2+y^2+z^2)/2$.

PROBLEMS FOR SOLUTION.

706. *Proposed by numerous contributors.*

Is there any simple proof of the formula for the area of a triangle in terms of its sides which does not involve trigonometry nor any complicated algebraic manipulations?

707. *Proposed by Daniel Kreth, Wellmann, Iowa.*

Construct $\triangle ABC$, given the base a, the difference $b-c$ of the sides, and the difference $\angle B-\angle C$ of the angles at the base.

708. *Proposed by Norman Anning, Ann Arbor, Michigan.*

Given $f(x) = x^4+x^3+x^2+x+1$, factor $f(x^2)$, $f(x^3)$, $f(x^4)$.

709. *Proposed by A. Pelletier, Ecole Polytechnique, Montreal.*

What are some of the various special cases of the problem of Pappus? (See solutions of 667 above). [This being a rather general question, the editor suggests we draw some figures for the cases (*a*) where the line ABC is a tangent or a secant, (*b*) AB = BC, (*c*) when will the inscribed triangles YTV and XZW coincide, or be isosceles, or equilateral?]

710. *For Undergraduates. Proposed by Walter R. Warne, Pennsylvania State College, State College, Pennsylvania.*

A, B, C are three buoys, AB = 320, BC = 435, CA = 600. A ship S finds that AB subtends an angle of 8° and BC an angle of 26°. How far is the ship from each of the buoys?

Solutions of problem proposed in April should reach the editor before August 25, in May before September 25, and in this number before October 25. Problems 704, 706, 709 deserve extra attention.

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QUESTIONS AND PROBLEMS FOR SOLUTION.

374. *Proposed for discussion by Mabel T. Rogers, Milledgeville, Ga.*

(*a*) If a pail of water weighs twenty-five pounds and a one-pound fish is put in without spilling any water, will the pail plus the fish weigh twenty-six pounds?

(*b*) What experimental data have you, or can you get on this problem? (Miss Rogers says that she tried it but "The fish were borrowed so that I could not risk weighing them out of water").

---

375. *Contributed from the Sporting Page of The Cleveland News, by A. W. Reckling, Apprentice, The Warner & Swasey Co.*

The Indians are going to experiment with a new headgear in batting practice. . . . . There is the very nicest little problem behind the head guard that you ever dreamed of. Here it is:

The ball weighs five ounces, is nine inches in circumference and travels the distance, sixty feet (pitcher's regulation distance) in one and one-half seconds.

What is the impact when the ball lands in the catcher's hand?

All the smart mathematicians around New York tried to work it out. . . . There is not a man identified directly in baseball that can give any light on it. Not one of the batters knows just what danger he faces each time he comes up to bat.

EXAMINATION PAPERS.

376. *Matriculation Examination, September, 1920. The University of Wales, Cardiff. Please send in solutions of problems numbered 377, 378 and 379.*

Experimental Mechanics and Heat.

377. A ball A of mass 1 lb. impinges directly on another ball B which is at rest, and after the impact the two balls move in opposite directions, each with a velocity equal to one-third of the original velocity of A. Find the mass of B.

378. If the coefficient of absolute expansion of mercury is 0·00018, and the coefficient of cubical expansion of glass is 0·000027, find what weight of mercury must be placed in a weight thermometer of internal volume 12 cubic centimeters, in order that the volume of the space above it should not vary when the temperature of the whole is raised.

[Density of mercury = 13·6 gms. per c.c.]

379. Two lead balls are suspended from a point by strings each of which

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is 2 metres long. The balls are drawn aside in opposite directions until the strings are horizontal and are let go at the same moment. Assuming that the balls collide when in their lowest positions, and that in the collision all the kinetic energy is converted into heat, which is retained by the balls, find their rise of temperature.

[Specific heat of lead = 0·03, mechanical equivalent of heat = 42 million ergs per calorie.]

UNIVERSITY OF ALBERTA.

High School and University Matriculation Examinations Board.

Departmental Examinations, 1920.

GRADE XI, CHEMISTRY.

Time—Two and one-half hours.

379.

Values.

1. Classify, giving reasons, one kind of change which takes place in each of the following experiments:

1 (*a*) Snow is melted in a vessel.

1 (*b*) A load of fresh grass cut from a lawn is left in a pile for several hours on a warm day.

1 (*c*) A piece of red-hot iron is hammered on an anvil and sparks fly from it.

1 (*d*) Dough is placed in a pan in a warm place.

1 (*e*) A sewing needle is drawn several times across the end of a bar magnet.

4 **2.** (*a*) State clearly two important distinctions between a mechanical mixture and a chemical compound.

4 (*b*) Give two examples of each kind of substance mentioned in (*a*).

3. A piece of pure zinc is placed in a beaker and covered with dilute hydrochloric acid and allowed to stand for a few moments. The zinc is then removed and a piece of platinum wire wrapped closely around it and again placed in the acid.

2 (*a*) What occurs when the zinc is first placed in the acid?

2 (*b*) What difference did the wrapping of the zinc with the platinum cause?

2 (*c*) What name is given to a substance which acts as the platinum did in this experiment?

2 (*d*) Name two other substances which have a similar effect on chemical action.

2 (*e*) What new substances are formed by this experiment?

4. (*a*) A small quantity of sulphur is ignited in a deflagrating spoon and lowered into a jar of oxygen, which is then covered. As soon as the reaction ceases a little water is poured into the jar which is then shaken. The resulting substance is then tested with litmus paper.

(*b*) A similar experiment is performed using metallic sodium instead of sulphur.

2 (1) Name the substances formed when the sulphur and sodium are lowered into the oxygen.

2 (2) State the results of the litmus tests.

2 (3) On the basis of the litmus tests classify the substances named in (1).

2 (4) What are the substances formed when water is added after combustion?

12 **5.** If the rate of pressure exerted by a certain weight of gas occupying 50 litres at a temperature of 20°C. be 700 mm., find the rate of pressure if the volume were changed to 20 litres and temperature to 30°C.

6. A small piece of sodium is placed on the surface of water contained in a soup plate.

2 (*a*) Accurately describe what happens.

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2 (*b*) Name the new substances formed.
2 (*c*) Repeat the experiment using hot water and indicate the difference in the reaction which takes place.
2 (*d*) Give a reason for this difference.
4 (*e*) Repeat the experiment again, but this time float the sodium on a piece of blotting paper. Describe and explain what takes place.

8 **7.** (*a*) Describe an experiment for the laboratory preparation of hydrogen peroxide.
4 (*b*) Write concise notes on the economic uses of this substance.

8. Pass carbon dioxide slowly through a combustion tube containing red-hot charcoal and apply a lighted taper to the gas evolved at the end of the combustion tube.
2 (*a*) Name the gas formed in the combustion tube and at the end of it.
4 (*b*) Write equations expressing the two reactions which take place.
2 (*c*) What property of charcoal is illustrated by this experiment?

12 **9.** A substance on analysis yields the following percentage of its constituents: Carbon 52.17%; Hydrogen 13.04%; Oxygen 34.78%. Find the simplest molecular formula of the substance.

5 **10.** (*a*) Describe a laboratory method for (1) the preparation and
3 (2) the collection of sulphur dioxide.
3 (*b*) Write the equation expressing the reaction which takes place in (*a*).

3 **11.** Show by description of experiments how you would identify
3 each of the following compounds: A chloride, a nitrate,
3 a sulphate, and a carbonate.
3

3 **12.** Express by equations the reactions which take place when
3 the following substances are prepared: Hydrochloric
3 acid, ammonia, nitric oxide, acetylene and carbon diox-
3 ide.

ARTICLES IN CURRENT PERIODICALS.

American Journal of Botany, for March; *Lancaster, Pa.;* $6.00 *per year*, 75 *cents a copy:* "A Study of Rhus Diversiloba with Special Reference to its Toxicity," James B. McNair; "The Effect of Salt Proportions and Concentrations on the Growth of Aspergillus Niger," C. M. Haenseler; "Suggestions with Respect to the Measurement of Osmotic Pressure," L. Knudson and S. Ginsburg; "Thick-walled Root Hairs of Gleditsia and Related Genera," W. B. McDougall; "A Simple Method for Growing Plants," J. M. Brannon.

American Mathematical Monthly, for April; *Lancaster, Pa.;* $4.00 *per year*, 45 *cents a copy:* "The January Meeting of the Kansas Section," E. B. Stouffer; "The December Meeting of the Maryland-Virginia-District of Columbia Section," O. S. Adams; "On Certain Properties of Makeham's Laws of Mortality with Applications, H. L. Rietz; "Among my Autographs: 4. Monge and the American Colonies; 5. Descartes's Appreciation of Huygens the Elder," D. E. Smith; "Questions and Discussions: Discussions—'On Curves Whose Envelopes Are Similar Curves,' Dr. Philip Franklin; 'Geometric Proofs of the Law of Tangents,' R. M. Mathews; 'Expository Papers for the Association,' E. J. Wilczynski."

Condor, for January-February; *Eagle Rock, Los Angeles Co., California;* $2.00 *per year*, 40 *cents a copy:* "Acorn-Storing by the California Woodpecker" (with four photos), William E. Ritter; "Suggestions Regarding the Systema Avium," Richard C. McGregor; "A Hunter's Notes on Doves in the Rio Grande Valley," Aldo Leopold; "Concerning the Status of the Supposed Two Races of the Long-billed Curlew" (with two graphs), Joseph Grinnell; "Notes on Some Specimens in the Ornithological Collection of the California Academy of Sciences," Joseph Mailliard.

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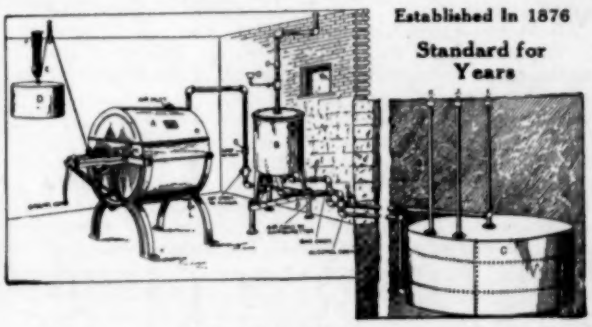

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Geographical Review, for April; *Broadway at 156 Street, New York City;* $5.00 *per year*, $1.25 *a copy:* "Agriculture and Landownership in Poland" (9 maps), Henryk Arctowski; "Physiography and Settlements in Southern Macedonia" (1 insert map in color, 4 text maps, 5 block diagrams, 1 insert photograph), Alan G. Ogilvie; "Some Highways of Albania and a Forgotten Riviera" (1 map, 6 photographs), George P. Scriven; "The Cahokia Indian Mounds: A Plea for Their Preservation" (1 illustration), Thomas H. English; "The Natural Regions of Mexico" (5 maps, 1 graph), E. M. Sanders; "The Distribution of Population in Mexico" (1 insert map in color, 1 insert map in black-and-white, 7 photographs), Sumner Cushing; "The Relation of Health to Racial Capacity: The Example of Mexico" (2 graphs, 8 maps), Ellsworth Huntington; "Recent History and Present Status of the Vinland Problem" (1 map), W. H. Babcock; "Plover Land and Borden Land" (1 map, 1 sketch), Vilhjalmur Stefansson.

Journal of Geography, for March; *Menasha, Wis.;* $2.00 *per year*, 25 *cents a copy:* "The Illinois Ozarks," Helen M. Strong; "The Boats in San Francisco Harbor," Helen M. Reynolds; "Economic Opportunities in the Southern Appalachians," Julia McCarthy; "A Method of Teaching Map Geography," John L. Horn.

National Geographic Magazine, for April; *Washington, D. C.;* $4.00 *per year*, 50 *cents a copy:* "Modern Persia and Its Capital" (47 illustrations), F. L. Bird; "Persian Caravan Sketches" (63 illustrations), Harold F. Weston.

Nature-Study Review, for March; *Ithaca, N. Y.;* $1.50 *per year*, 20 *cents a copy:* "Long's Trail School," E. A. Mills; "Waking Up Dead Back Yards," W. R. Beattie; "Symposium of Garden Supervisors from Coast to Coast"; "Do We Need School Museums," E. K. Peeples and E. Dyer; "Vote for a National Tree"; "Children's Gardens in a Steel Town," L. S. Thomas.

Photo-Era, for March; *Boston, Mass.;* $2.50 *per year*, 25 *cents a copy:* "The Camera in Algeria and Tunisia" (Part II), Herbert B. Turner; "Retouching for the Amateur" (In Three Parts) (Part I), Dr. H. Graschopf; "Fundamentals of Print-Criticism and Appreciation" (Part III), August Krug; "Developing Sensitive Plates by Candlelight," Photographische Industrie; "The Kodak Park Camera Club," E. P. Wightman; "The Child in Photography," Harrington's Journal.

Popular Astronomy, for April; *Northfield, Minn.:* "Measuring the Stars with the Interferometer," H. C. Wilson; "Latitude Without Instruments," Russell W. Porter; "The Collimation of a Reflecting Telescope," Alice H. Farnsworth; "Some Results Obtained with the Selenium Cell," Lewis J. Boss; "Legends of the Creation," Rufus O. Suter, Jr.; "Twenty-Fifth Meeting of the American Astronomical Society" (Continued).

Popular Science Monthly, for March; *New York City*, $3.00 *per year*, 25 *cents a copy:* "Shall I Invest in Oil," Guy E. Mitchell; "Piping Coal to New York City: Its Wings Carry the Engine," Latimer J. Wilson; "A Hopper's Life Is Not an Easy One"; "The Strange Power of the Tides," Philip Schwarzbach; "Using Trucks Instead of Conveyors"; "When Motor-Truck Trailers Pay," Joseph Brinker.

School Review, for April; *University of Chicago Press;* $2.50 *per year*, 30 *cents a copy:* "The Actual Objectives of the Present-Day High School," Franklin Bobbitt; "Attendance Procedure," H. V. Church; "The Portion of the High-School Program That May Advantageously Be Given to Vocational Work," H. N. Goddard; "Motives Utilized in Successful Publicity Campaigns for Better School Support," Carter Alexander; "Dormitories in Connection with Public Secondary Schools," Edith A. Lathrop.

Scientific Monthly, for April; *Garrison, N. Y.;* $5.00 *per year*, 50 *cents a copy:* "The History of Physics," the late Henry A. Bumstead, "Periodical Cicadas in Baltimore, Md.," E. A. Andrews; "The Biology of Death—Conditions of Cellular Immortality," Raymond Pearl; "Motion Pictures and Crime," Dr. A. T. Poffenberger; "An Italian Book on Empedocles," Dr. Jonathan Wright; "Perfect and Amicable Numbers," L. E. Dickson; "Climate and Health with Special Reference to the United States," Robert DeC. Ward.

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This letter strikes the keynote for the Central Association for the coming year, and the Membership Committee wishes to second the sentiment. This is the year of opportunity and of obligation for the teachers of science and mathematics. The Central Association is going to St. Louis November 25 and 26 this year, and St. Louis will welcome the Association with real St. Louis hospitality. Many new members from the South-central States will come to this meeting. It is sure to be a big, stimulating, and inspiring occasion. Don't fail to come to this meeting.

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When you have finished reading this number, hand it to a fellow craftsman and ask him to send in an application for membership. Do it *now!*—[The Membership Committee; Charles S. Webb, Chairman, Soldan High School, St. Louis, Mo.

HEAD OF A NEW BOTANICAL INSTITUTE.

Dr. William Crocker, Associate Professor of Botany in the University of Chicago, who received his Doctor's degree from that institution in 1906, has just been made director of the newly founded Thompson Institute for Plant Research at Yonkers, New York. He will enter on his duties next autumn.

The Board of Trustees of the new foundation will consist of three business men and three scientific men. Professor John M. Coulter, Head of the Department of Botany at the University of Chicago, and Mr. Raymond F. Bacon, of the Mellon Institute of Pittsburgh, (Ph.D., University of Chicago), will be two of the scientific men, and these two will select a third.

The new Institute for Plant Research is regarded as of the greatest importance in the development of botanical science.

PROFESSOR A. A. MICHELSON AT THE UNIVERSITY OF PARIS.

Professor A. A. Michelson, Head of the Department of Physics at the University of Chicago, is now acting as Exchange Professor at the University of Paris. His course of lectures will be on the general subject of "Physics" and will be given in the French language.

Professor Michelson's researches in light brought him the Nobel Prize of $40,000, and his recent measurement of the diameter of the bright star Betelgeuze in the constellation of Orion by means of the interferometer, an astronomical device of his own invention, has attracted world-wide attention.

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SOME PERSISTENT ERRORS IN GEOGRAPHY TEACHING.

By A. E. Parking,

George Peabody College for Teachers.

It is no exaggeration to say that 75 per cent of the geography teachers in our public schools have never had a systematic course in geography as given in our better normal schools and universities. And since the teachers who taught these teachers had had a similar preparation for their geography teaching there are extant in our teaching many errors that have come down from past generations. In spite of many excellent texts in geography now in general use such errors are likely to persist until every teacher who teaches geography is required to have adequate preparation. Such preparation in a subject as highly technical and broad as geography is cannot be secured in less than one full year in our best normal schools. No amount of methods courses in geography can atone for the errors of the past in neglecting this most vital subject in our curriculum. What is needed is solid content work.

In the brief space permitted in this article only a few of the more common errors may be discussed.

Climate is frequently thought of as only temperature. The climate of a place includes the temperature, pressure, moisture (rainfall and humidity), sunshine, and winds.

Another common error concerns the influence of the Gulf Stream on the climate of Europe. The statement is often made that "the Gulf Stream warms Europe" or "gives Europe a warmer climate." A more correct statement of the influence would be as follows: Winds off the Gulf Stream Drift moderate the temperature of western Europe over which they blow, making it *cooler in summer* and *warmer in winter* than lands farther east in the same latitude. These winds not only moderate the temperatures but bring in moist air to the continent. This moist air tends to prevent extremes in temperature and also gives western Europe much rain.

The Trade Winds are thought of by many teachers and students as blowing from 23½ degrees toward the equator. Although winds are due to differences of pressure, and temperature influences pressure, and the tropics (23½ N. and S. of equator) bound the Torrid Zone, there is no connection between the tropics of Cancer and Capricorn and the wind belts. The Northeast Trades blow from high pressure centers about thirty-five degrees north of the equator and the Southeast Trades blow equatorward from similar centers about thirty degrees south. These high pressure centers are, therefore, not at the Tropics.

The presence of the prairies and grasslands of North America is often described as due to the fires set by the Indians to produce better pasture for the buffalo. This is not the explanation that is held by plant geographers who have studied the grasslands. They contend that the vegetation of the grasslands is the result of a particular climate that is adverse to trees, that grassland vegetation is to be found the world over where the rainfall is moderate and is distinctly seasonal, where the air is dry, and, where the winds are strong so that evaporation and transpiration are rapid. This is the condition in the western portion of the Mississippi Basin. The fires may have benefited the pastures and certainly would kill young saplings but the Great Plains were grasslands long before the Indians came to hunt the buffalo and also were there long before the buffalo.

"Hot air rises and cold air rushes in to take its place" has long been the current explanation of the cause of winds. This is equivalent, as one teacher puts it, to saying that a person going from a lower floor to an

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upper in a store by way of the elevator ascends the elevator shaft and the elevator follows after. The warm air, even though warm, cannot move unless pushed up. Neither does the cold air rush in to take its place, but it moves in and displaces the warmer air. A correct statement might be somewhat as follows: Air when heated expands and becomes lighter per unit volume. The cooler and heavier air about pushes in beneath the warmed air. The air that moves from the cooler to the warmer region, near the surface of the ground, is known as wind. This explanation does not explain all winds. It is safer to say that winds blow from high pressure areas to regions of low pressures. But inasmuch as the conception of pressures is a difficult one for children, it is the writer's opinion that the cause of winds should not be discussed in the grades. In geography we are not much concerned with the cause of winds but with the effects. The cause of winds is a meteorological question.

It is a well known generalization, and scientifically sound, that the windward sides of the highlands and mountains receive more rain than the lee sides. This greater rainfall is often taught as due to the ascending air coming in contact with the snows on the mountain or being mixed with the cooler air of the higher altitudes. The facts are that the air that ascends is cooler than the snows or the air in contact with the mountains. That standard explanation is not correct. The sequence of changes that occur may be described as follows: The ascending air expands, because it gets into regions of less pressure, and cools, because of this expansion. This cooling condenses the moisture in the ascending air and rain results.

Conversely, when the air passes over the highland or the mountain it descends on the lee side because it is drawn down by gravity and in descending is warmed and its capacity to contain moisture is increased. It, therefore, becomes a drying wind. The statement that it is dry on the lee side because the air has lost its moisture on the windward side is not correct. It is not the loss of moisture that makes air dry but the warming of the air in the descent. At the highest point in the ascent, before the descent begins, the air is very moist.

BOOKS RECEIVED.

Catalogue of High School and College Textbooks, Ginn & Co., pages XII plus 395. 12½×18½ cm. Paper. 1921. Ginn & Co., Boston, Mass.

A History of the Teaching of Chemistry in the Secondary Schools of the United States, Previous to 1920, Samuel R. Powers. 15×22½ cm., 68 pages. Paper. 1920. 50 cents. University of Minnesota, Minneapolis.

Catalogue of the Cambridge Botanical Supply Company, Waverley, Mass. 144 pages. 15×22½ cm. Paper. 1920. Cambridge Botanical Supply Co., Waverley, Mass.

Carnegie Foundation for the Advancement of Teaching, 15th Annual Report of the President and of the Treasurer. Pages VII plus 171. 17½×25 cm. Paper. 1920. The Carnegie Foundation, 522 Fifth Ave., New York City.

Biology for High Schools, by W. M. Smallwood, Syracuse University, Ida L. Reveley, Wells College, and Guy A. Bailey, Geneseo Normal School. Pages xxiii+550+40. 13.5×19 cm. Cloth. 1920. Allyn and Bacon, Chicago.

A Problem Course in Chemistry, by David B. Pugh and D. Edwin Miller, Schenley High School, Pittsburgh. Pages xv+135. 13.5×19 cm. Cloth. 1921. Allyn and Bacon, Chicago.

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Everyday Science, by William H. Snyder, Hollywood High School, Los Angeles. Pages xviii+645+26. 13.5×19 cm. Cloth. 1919. Allyn and Bacon, Chicago.

Chemistry Review Book, by M. H. Kessel, Clark School, New York City. 96 pages. 15×23 cm. Paper. 1921. Globe Book Company, 175 Fifth Ave., New York City.

Transactions of the Illinois State Academy of Science, Vols. xi, xii, and xiii. 197, 299 and 351 pages. 15×23 cm. Paper. 1918, 1919, 1920. The State Museum, Springfield, Ill.

BOOK REVIEWS.

The Fundamentals of Argumentation and Debate, J. Walter Reeves, Peddie Institute, Hightstown, N. J. Pages vi+82. 11½×17 cm. Cloth. 1920. D. C. Heath & Co., Boston.

The author of this little book does not claim to have any phenomenal method of handling the material here presented, nor does he claim to have covered the subject completely. He has in mind, rather, the idea of presenting the subject so that it will be easily and clearly understood. The idea of argumentation is not generally understood by High School pupils, but the object of this work is to make it clear to them. It is an interesting little book to put into the hands of pupils taking part in debating clubs in secondary schools. The book should have a wide circulation. C. H. S.

Elementary Electrical Engineering, Ralph P. Clarkson, Acadia University, Wolfville, N. S. Pages xvi+187. 14×19 cm. Cloth. 1920. $2.00 net. D. Van Nostrand Co., New York City.

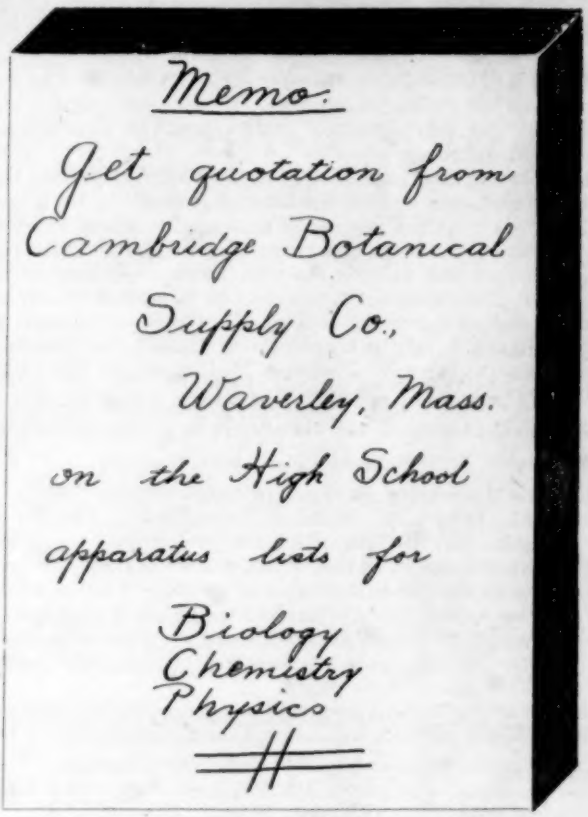
This book was written primarily for use by those students who expect to become mechanical, civil, or chemical engineers. It is primarily of an elementary nature, but at the same time it presents to the student the fundamental phases of electrical engineering. It being a rather compact treatise, it is then necessarily brief in its discussions of most of the topics. There are no superfluous words used. The book is of such a nature that the work should be supplemented by laboratory instruction.

There are 143 half-tones and drawings that have been especially selected to illustrate the work in question. There are six chapters and a list of diagrams and half-tones. There are a number of tables of constants scattered throughout the book. The major paragraphs all begin with bold-faced type. Throughout there are many practical problems given. There is a good index and mechanically the book is well-made and deserves a large circulation. C. H. S.

An Outline of Physics, by L. Southerns. Pages xv+202. 13×19 cm. Cloth. 1920. $2.50 net. E. P. Dutton & Co., 681 Fifth Ave., New York City.

The author of this text believes that a person to be well grounded in the principles of physics should have a complete and clear understanding of the elementary principles, which must be studied during his first year, and that they should be presented in such a way as to inspire the student to continue his course in the subject. The author believes that the newer discoveries in physics should be incorporated with the older ideas and principles, as the student progresses in the subject, he believing that the newer phases are no more difficult to understand than the older laws.

The book is well-written and easy to understand. The principles and laws stated therein are correct. There are ninety-five figures, most of which were drawn especially for this book. It is printed on uncalendered paper and contains a very good index. It is a valuable book for any physicist to possess. C. H. S.



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Illinois Arbor and Bird Days, Circular No. 151; compiled by Francis G. Blair, Supt. of Public Instruction, Illinois. 68 pages. 59 illustrations. 15×23 cm. Paper. 1921. Dept. of Public Instruction, Springfield, Illinois.

This is a splendid little pamphlet, gotten out for distribution throughout the schools of the state of Illinois, although it might be used in any state in the union. It is for the purpose of encouraging school children to take greater interest in our birds and trees, encouraging them to plant more trees and not ruin and destroy the wild flowers. It also endeavors to get them to do everything they possibly can to protect the birds.

There are many interesting articles of interest to children, especially that by Frank Smith, of the University of Illinois, on "Illinois Birds as Travelers;" also a paper by Professor McDougall, of the University of Illinois, on "Plant Communities." The little pamphlet will surely do a world of good in helping the youngsters to encourage tree and shrub planting and the protection of birds. C. H. S.

Suggestions for Laboratory Exercises in Optics. Pages 24. 18×25 cm. Paper. 1921. Price $.25. Standard Scientific Co., New York City.

This is a splendid little pamphlet, containing some thirty-eight very interesting experiments in optics, which can be carried out by means of this firm's new Farwell-Stifler optical bench. The experiments are printed and they are all ready to put into the hands of the pupil. Instructors who have been at a loss as to how to carry out the more recent experiments in optics should possess themselves of this little pamphlet and put it into the hands of their pupils.

A price-list of the various parts and accessories to the bench are given. Undoubtedly there will be a big demand for the pamphlet. C. H. S.

Biological Equipment, Catalog 91, Cambridge Botanical Supply Co., Waverly, Mass. 144 pages, 15x22½ cm. Paper. 1921. Cambridge Botanical Supply Co., Waverly, Mass.

This is a brand new and up-to-date catalog of this well known firm's catalog of botanical, zoological and psychological apparatus. There are many new pieces of apparatus listed. It's profusely illustrated and the descriptions of the apparatus are such that the buyer will have no trouble in understanding just what the apparatus or material is like from the description given in the catalog.

There are 16 sections to the book, each section devoted to a branch of biological work. This makes it very easy to locate quickly the desired place where the description of the apparatus will be found. Directions for forwarding orders, shipments and the prices of the apparatus is given. There is also a splendid list of lantern slides. There is a very complete index of 8 pages. See their full page advertisement on page 603 of this journal. This house not only deals in biological apparatus, but they make a specialty of physics and chemistry material described in their catalogs 93, 94 and 95. C. H. S.

Elements of Plane Geometry, by Charles Davison, Sc. D., formerly Mathematical Master at King Edward's High School, Birmingham. Pages, 280. 13×19 cm. 1920. Cambridge University Press.

While this text-book has many points of excellence, the chief one is the large number of exercises. With few exceptions each theorem is followed by a set of exercises, which are direct applications of the theorem. In each chapter, each theorem except the first is succeeded by a set of miscellaneous exercises; and at the end of each chapter are exercises of greater difficulty. Teachers will find this a very useful book for reference. H. E. C.

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Elements of Physics, by R. A. Houston, University of Glasgow. 202 figures. Pages viii+221. 14½×22 cms. Cloth. 1919. $1.20. Longmans, Green & Co., New York City.

This book is intended for a text-book in elementary physics. In order to understand all parts of it one ought to have a knowledge of the elements of trigonometry. A knowledge of the matter contained in this text will enable one to pass the examination for admission into practically every college in this country, as well as Great Britain.

The author seems to think that physics of the future will be taught more from a systematic standpoint or lecture method than from the laboratory and note-book method. The reviewer disagrees with him in this.

Many of the cuts have not been brought down to date and are really passe. There are many practical questions scattered throughout the book, especially at the end of the various chapters.

There are appendixes, one containing answers to problems, and the index is complete. C. H. S.

Second Book in Algebra, by Fletcher Durell, Ph. D., Head of Department of Mathematics, The Lawrenceville School, and E. E. Arnold, M. A., Supervising Principal, The Public Schools of The Pelhams, N. Y. Pages v+330. 13×19 cm. 1920. Charles E. Merrill Company, New York.

This book consists of two parts. Part One contains work for classes giving a half year to the second course in algebra, while the entire volume covers the ground for an entire year given to the second course. The features which distinguish the authors' *First Book in Algebra* are continued and developed. Extensive use is made of the graph, and in the treatment of the formula the pupil is asked more frequently to supply the letters and make up the complete formula. Verbal problems are given in abundance, and there are many examples which require the pupil to invent and solve problems to meet given sets of conditions. H. E. C

Essentials of Arithmetic, by Samuel Hamilton, Ph. D., LL. D., Superintendent of Schools, Allegheny County, Pa. Lower Grades. Pages 222. Middle Grades, pages 284. Higher Grades, pages 320. 13×19 cm. 1920. American Book Company, New York.

This series has aimed to lay equal stress on two important ends sought in the teaching of arithmetic: (1) To give the pupil such a mastery of combinations and processes as will enable him to perform with accuracy and speed all common numerical operations and (2), to train him in the skillful application of these processes to the problems that he is likely to meet in his daily experiences. The problems deal with the things in which pupils are interested. At first they deal entirely with his life at home, at school, on the street, and in the playground; but gradually they reach out to include his contact with social and industrial life. The pupil's self-activity is utilized in constructive work and in forming original problems, and his initiative is exercised by leading him to discover many arithemetical truths for himself. The print is in large, clear type, and many pictures and drawings embellish the pages. The first book covers the work of the second, third, and fourth years; the second, the fifth and sixth years; the third, the seventh and eighth years. H. E. C.

Geometry Review Book, by M. J. Leventhal, Instructor in Mathematics, Stuyvesant High School, New York City, and M. Weiner, Chairman of the Department of Mathematics, New Utrecht High School, Brooklyn, N. Y. Pages 86. 15×23 cm. 1920. Paper covered. The H. S. Review Book Co., New York.

This book is a response to the demand by both teachers and pupils for a review book, which will be a genuine aid in the compact and concise presentation of the usual course in geometry with due emphasis upon the

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pedagogical as well as the logical aspects of the subject. The selection and arrangement of the theorems meet the precise requirements of the New York State Education Department. Simple proofs are either omitted or briefly outlined. In the selection of exercises stress has been laid upon numerical and construction programs, so-called practical problems, and exercises taken from Regents and College Entrance examination papers. The book seems extremely well adapted to its purpose of preparing pupils to pass an examination. H. E. C.

Die Starre, by Geheimem Regierungsrat Professor Hermann Hahn, Leiter der staathchen Hauptstelle für den naturwissenschaftlichen Unterricht. Pages 78. *Die Schraubenfeder, by Oberlehrer Dr. Curt Fischer, Mitleiter der physikalischen Lehrgänge und der Prüfabteilung der staathchen Hauptstelle für den naturwissenschaftlichen Unterricht.* Pages 109. 18×26 cm. 1920. Paper. Quelle & Meyer, Leipsic.

These two monographs form Heft 4, Band 1 of Mitteilungen der Preussischen Hauptstelle für den naturwissenschaftlichen Unterricht. The main divisions of *Die Starre* are, Die gedehnte Schraubenfeder in Ruhe, and Die schwingende Schraubenfeder; of *Die Schraubenfeder*, Verhalten der Feder beim Dehnen, and Die schwingende Schraubenfeder. Students of physics will find much of interest in this treatise on the helical spring. H. E. C.

Plane Geometry, by H. E. Hawkes, Ph. D., Professor of Mathematics in Columbia University, W. A. Luby, M. A., Head of the Department of Mathematics in the Junior College of Kansas City, and F. C. Touton, Ph. D., Supervisor of High Schools, Wisconsin. Pages vii+305. 13×19 cm. 1920. $1.32. Ginn and Company, Boston.

The chief aim of the authors has been to plan the work so that the pupil will develop power to solve original exercises. With no waste of time theorems are reached which have numerical applications. The solution of these numerical problems prepares the pupil to begin the devising of general proofs having to do with congruent triangles. Axioms, postulates, and definitions are not given till needed. Numerical and general applications of a theorem are placed immediately after it, and fifteen pages of exercises are grouped at the end of the text. Among the exercises are a good number of algebraic and graphical exercises. Numerous notes give historical information, and call the attention of teacher and pupil to important points in proofs and constructions.

H. E. C.

Factory Chemistry, by William H. Hawkes, A. B., M. Sc., Dept. of Chemistry, Ford Institute of Technology, Detroit, Mich. First edition. Pages vii+39. 1.2×13×19 cm. Not illustrated. Cloth. 1921. $1 net. Longmans, Green & Co.

This little manual is a very much condensed account of the more fundamental parts of elementary inorganic chemistry. It is frankly designed for the use of men in a plant that maintains a metallurgical laboratory. It attempts to give them the irreducible minimum of work prerequisite to a course in qualitative and quantitative metallurgical analysis. The order of treatment follows: Introduction, valence, definitions and chemical terms, chemical laws, composition, properties and construction of acids, bases and salts; classes of salts, hydroxides, chemical equations, classes of equations, mathematics of chemistry and lastly some twenty pages of qualitative analysis.

Those teachers who are placed in a position where a little chemistry will be better than none would do well to investigate this book.

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Laboratory Experiments in Organic Chemistry, Designed especially for use with Stoddard's Introduction to Organic Chemistry, by E. P. Cook, A. M., Associate Professor of Chemistry in Smith College. Second edition. Pages ix+83. .7×12.5×18.7 cm. Eight figures. Cloth. 1920. $1 net. P. Blakiston's Son & Co.

This second edition, like its predecessor is designed "to illustrate and emphasize the more important methods of preparation of the various classes of organic compounds to show the typical reactions of each class and to instruct the student in the details of organic laboratory work." It is intended to afford material for a laboratory course of four hours a week for one year. Like the text it is intended to accompany, this laboratory manual seems to be an excellent book. F. B. W.

A Problem Course in Chemistry, by David B. Pugh and D. Edwin Miller, Schenley High School, Pittsburgh. First edition. Pages xv+135. 1.2×12.5×19 cm. Unillustrated. Cloth. 1921. Allyn & Bacon.

As the title suggests, the book contains hundreds of numerical problems, taken from many parts of the usual course in general inorganic chemistry. These problems are grouped by subjects, as, for example, oxygen, hydrogen, compounds of oxygen and hydrogen, heat measurement, writing and balancing equations, nitrogen and the atmosphere, the gas laws, etc. Occasionally a brief paragraph is devoted to explaining some fundamental point, as the nature of the reaction between an acid and a base, but, in the main, the book is a succession of problems. In the case of some of the more complicated problems a sample solution is given or the method of solution is presented but in general it is left to the teacher to present the method of solving the problems. The book should be a valuable adjunct to the text used by any teacher. F. B. W.

Chemistry Review Book, including recent examination questions, by M. H. Kessel, B. S., Science Master in the Clark School for Concentration, New York City, author of Physics Review Book. First edition. Pages 96. .5×15.3×23 cm. 15 figures. Paper. 1921. Globe Book Co., New York.

The book is designed to assist the teacher who has to prepare students for the regents or the college entrance board examinations in chemistry. It looks like a very through-going review book for that purpose. It groups the laws and theories in a preliminary chapter by themselves. This is followed by a chapter on chemical arithmetic and one on chemical formulas and equations. Then the various non-metals and metals are reviewed and later a little organic chemistry is taken up. An appendix with definitions, a summary of equations, a series of standard tests and various tables is followed by sample sets of examinations chosen from among recent College Board and Regents Examinations. The book should prove very useful in its intended field. F. B. W.

Practical Chemistry, fundamental facts and applications to modern life. by N. Henry Black, A. M., Science Master, Roxbury Latin School, Boston, Mass., and James Bryant Conant, Ph. D., Assistant Professor of Chemistry, Harvard University. 1920. Pages x+474. 2.2×13.5×19 cm. 257 figures. Cloth. 1920. The Macmillan Co.

The keynote to this new text seems to be an attempt to arouse interest on the part of the pupil by means of presenting, usually as demonstration experiments, some of the many striking, not to say startling experiments which are available to the teacher of chemistry, and to relate, so far as is possible, the remaining matter of the text to the student's fund of experience. The subject-matter and the order of presentation show no striking

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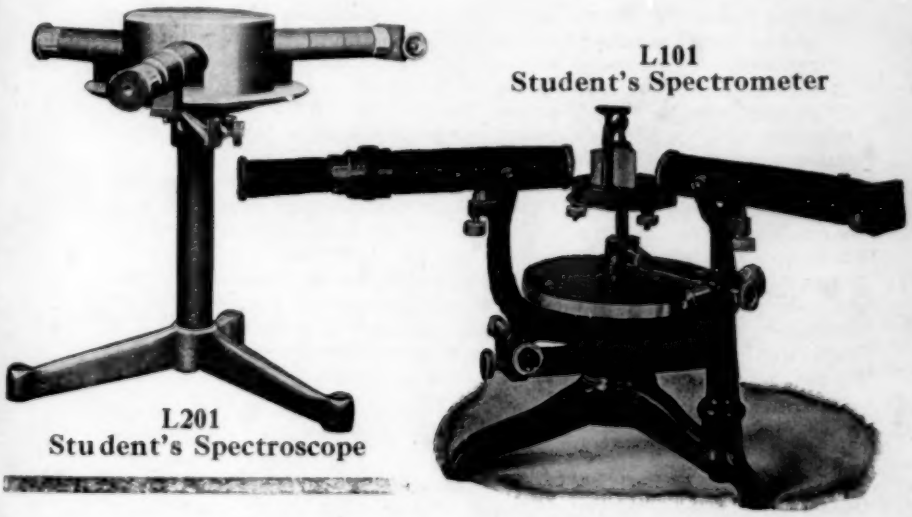

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departure from that with which we are familiar. The authors have, however, succeeded to a considerable degree, especially in the earlier part of the book, in dressing their facts in modern garb. One frequently sees references to recent events and practices, especially to matters connected with the great war.

The theoretical parts of the text are well and scientifically presented. This is especially true of the chapters on atomic and molecular weights. One is moved to wonder if high school pupils will be able to comprehend quite all that is offered them.

The pictures with which the text is generously illustrated are well-selected. The industrial pictures in particular are excellent.

The modern electronic conception of electrical phenomena is brought into the discussion of the primary cell, although the discussion of the storage cell is not thus modernized. The reviewer is glad to see someone venture to thus present to secondary school pupils a conception that, properly presented should clear up rather than cloud the pupils' understanding of ionic reactions.

The book is strikingly modern in many ways and merits investigation by all teachers of High School chemistry. F. B. W.

Under the title of, *"Parallaxes of 260 Stars," the Columbia University Press of New York* has issued a valuable contribution to exact astronomical research. The volume is No. 9 of the publications of the Ernst Kempton Adams Fund for Physical Research.

The parallaxes have been derived by Professor L. A. Mitchell of the University of West Virginia, from photographs made at the McCormick Observatory of the University.

Preceding the tables of parallaxes that form the bulk of the volume is a concise, historic description of the various methods that have been used to obtain parallax. After a brief account of the limitations of the earlier methods of obtaining parallax—by "meridian circle" and "heliometer"—the advantages and difficulties of the photographic determination of parallax are described in considerable detail. Altogether this introductory description of the modes of determining parallax is so well done that it might well be printed separately for a wider distribution than is possible for the rather bulky and expensive complete volume. J. F. M.

Textbook of Pastoral and Agricultural Botany, by John W. Harberger, Ph. D. Size 14×19 cm., with 294+ix pages and 121 illustrations. P. Blakiston's Son & Co.

This book is the result of Professor Harberger's work with his own classes in the University of Pennsylvania. As his classes were composed of veterinary students we are not surprised to find the subject matter related to the needs of this class of students. The first nine chapters are devoted to stock-killing plants. Probably this is the most comprehensive study of such plants that we have. Other chapters discuss feeds and feeding, forage grasses and important cereals. There are three chapters on the leguminosae, including the nitrogen-consuming plants, briefly described and classified. Weeds and weed control have one chapter and the book closes with a chapter on seeds and seed-testing.

Some particularly useful things in the book are the bibliographies with each chapter and the classification of the nitrogen-consuming crops, according to the portion of the plant useful—into root crops, bulb crops, stem crops, etc. The subject-matter is compactly stated. We believe the book will be a very useful reference book for those teachers of both botany and zoology, who like to present the practical aspects of their subject. W. W.